428 Rec'd PCT/PTO 27 JAN 2000

FORM PTO-1390
(REV 12-29-99)

U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: CU-2114 TJK

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 09/463541

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB98/02329	03 August 1998	01 August 1997

TITLE OF INVENTION
POWER ADAPTION IN A MULTI-STATION NETWORK

APPLICANT(S) FOR DO/EO/US
Mark Sievert LARSEN et al

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [X] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [X] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [ ] Other items or information:

Express Mail Label No.
EL467817287US

U S APPLICATION NO (if known, see 37 CFR 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/463541	PCT/GB98/02329	T.IK

428 Rec'd PCT/PTO 27 JAN 2000

17. [X] The following fees are submitted:	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$970.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$840.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$690.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$670.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$96.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 840.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	23 - 20 =	3	X **$18.00**	$ 54.00	
Independent claims	2 - 3 =	0	X **$78.00**	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$260.00**	$	
TOTAL OF ABOVE CALCULATIONS =				$ 894.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 894.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 894.00	
				Amount to be refunded:	$
				charged:	$

a. [X] A check in the amount of $ 894.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 12-0400. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Ladas & Parry
224 South Michigan Avenue
Chicago, Illinois 60604
(312) 427-1300

January 27, 2000

SIGNATURE

Timothy J. Keefer
NAME

35567
REGISTRATION NUMBER

Applicant or Patentee: SALBU RESEARCH AND DEVELOPMENT (PROPRIETARY) LIMITED Attorney's
Serial or Patent No.: _____ Docket No.: _____
Filed or Issued: 27 JANUARY 2000
For: POWER ADAPTION IN A MULTI-STATION NETWORK

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (c)) — SMALL BUSINESS CONCERN

I hereby declare that I am

[ ] the owner of the small business concern identified below:
[X] an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN SALBU RESEARCH AND DEVELOPMENT (PROPRIETARY) LIMITED
ADDRESS OF CONCERN PORTION 86-87 OF FARM DOORNKLOOF, PRETORIA, 0002, SOUTH AFRICA

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9 (d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled POWER ADAPTION IN A MULTI-STATION NETWORK by inventor(s) MARK SIEVERT LARSEN; JAMES DAVID LARSEN described in

[ ] the specification filed herewith
[X] application serial no. 09/463,541, filed 27 JANUARY 2000.
[ ] patent no. _____, issued _____.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9 (d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9 (d) or a nonprofit organization under 37 CFR 1.9 (e).

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME _____
ADDRESS _____
[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME _____
ADDRESS _____
[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING James David Larsen
TITLE OF PERSON OTHER THAN OWNER Director
ADDRESS OF PERSON SIGNING Portion 86-87 of Farm Doornkloof, Pretoria, 0002, South Africa

SIGNATURE _____ DATE 10 February 2000

09/463541
428 Rec'd PCT/PTO 27 JAN 2000

DOCKET: CU-2114 TJK

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

APPLICANT: Mark Sievert LARSEN et al)
)
TITLE: POWER ADAPTION IN A MULTI-STATION NETWORK)
)
COMPLETION OF PCT/GB98/02329 filed August 3, 1998)

The Assistant Commissioner for Patents (DO/EO/US)
Box PCT
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Dear Sir:

Please amend the application being filed herewith under 35 USC 371.

IN THE CLAIMS:

Please amend claims 3, 7, 8, 10-13, 17, 20-23, from the International Preliminary Examination Report, as follows:

-- 3. (Once Amended) A method according to [claim 1 or] claim 2 wherein the path quality at a station receiving a data transmission is calculated by comparing the measured power of the received transmission with data in the transmission indicating the transmission power thereof.

7. (Once Amended) A method according to [any one of claims 1 to] claim 6 wherein each station monitors the transmissions of other stations to obtain path quality data therefrom, so that a first station monitoring a transmission from a second station within range of the first station to a third station our of range of the first station can obtain path quality data relating to the third station.

8. (Once Amended) A method according to [any one of claims 3 to] claim 7 including monitoring, from a first station transmitting data, the background noise/interference at a second station receiving a data transmission and adjusting

the transmission power value at the station transmitting data to the receiving station, thereby to maintain the required signal to noise ratio at the receiving station.

10. (Once Amended) A method according to claim [8 or claim] 9 including adjusting the data rate of message data transmitted from a first station to a second station according to the transmission power value set at the first station and the required signal to noise ratio at the second station.

11. (Once Amended) A method according to [any one of claims 8 to] claim 10 including adjusting the length of message data packets transmitted from the first station to a second station according to the transmission power value set at the first station and the required signal to noise ratio at the second station.

12. (Once Amended) A method according to [any one of claims 1 to] claim 11 wherein each station monitors the transmission of other stations to obtain background noise/interference data therefrom, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain background noise/interference data relating to the third station.

13. (Once Amended) A method according to [any one of claims 1 to] claim 12 including selecting, opportunistically, a station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith.

17. (Once Amended) Communication apparatus according to [claim 15 or] claim 16 wherein the processor means is arranged to extract path quality data from received transmissions, to compare the path quality data with the measured power of received transmissions, and to calculate a path quality correction factor from the difference therebetween, the path quality correction factor being utilized by the control means to adjust the output power of the transmitter.

20. (Once Amended) Communication apparatus according to [any one of claims 14 to] claim 19 wherein the processor means is arranged to monitor path quality data in transmission from other stations, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of the range of the first station can obtain path quality data relating to the third station.

21. (Once Amended) Communication apparatus according to [any one of claims 18 to] claim 20 wherein the processor means is arranged to store path quality data for each of a plurality of stations and to set an initial transmission power value when initiating communication with any one of said plurality of stations according to the respective stored path quality data.

22. (Once Amended) Communication apparatus according to [any one of claims 14 to] claim 20 wherein the processor means is arranged to monitor background noise/interference data in transmissions from other stations, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain background noise/interference data relating to the third station.

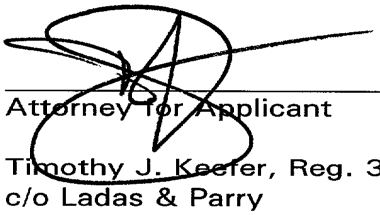
23. (Once Amended) Communication apparatus according to [any one of claims 14 to] claim 22 wherein the processor means is adapted to select, opportunistically, another station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith. - -

REMARKS

The application is presented for examination based on the specification pages 1-37 from the PCT international application as filed, claims 1-23 from the International Preliminary Examination report and including the foregong amendments, as well as the 18 sheets of figures.

The aforesaid claim amendments are presented to place the same in better condition for examination under U.S. rules of practice.

Respectfully submitted,



Date

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DOCKET ALARM

09/463541
PCT/GB98/02329
PTO/PCT Rec'd 27 JAN 2000

POWER ADAPTION IN A MULTI-STATION NETWORK

BACKGROUND OF THE INVENTION

This invention relates to a method of operating a multi-station communication network and to communication apparatus usable to implement the method.

International patent application no. WO 96/19887 describes a communication network in which individual stations in the network can send messages to other stations by using intermediate stations to relay the message data in an opportunistic manner. In networks of this kind, and in other multi-station networks, it is desirable to control the output power of transmitting stations to a level which is sufficient for successful reception of transmitted data, but which is otherwise as low as possible, to minimise interference with nearby stations or with other users of the radio frequency spectrum.

It is an object of the invention to provide a method of operating a multi-station communication network which addresses the above objective.

SUMMARY OF THE INVENTION

According to the invention there is provided a method of operating a communication network comprising a plurality of stations able to transmit data to and receive data from one another, the method comprising:

monitoring, at each station, the path quality between that station and each other station with which that station communicates;

recording, at each station, path quality data corresponding to the path quality associated with each said other station; and

setting, at each station, a transmission power value based on the recorded path quality data associated with a selected other station when transmitting data to said selected other station, thereby to increase the probability of transmitting data to said selected other station at an optimum power level.

The monitoring of path quality between stations may include monitoring at least one of the path loss, phase distortion, time delay, Doppler shift and multipath fading characteristics of a channel between the stations.

The method preferably includes transmitting path quality data corresponding to the path quality between a first and a second station when transmitting other data between the stations, so that path quality data recorded at the first station is communicated to the second station for use by the second station and vice versa.

The path quality at a station receiving a data transmission may be calculated by comparing the measured power of the received transmission with data in the transmission indicating the transmission power thereof.

A station receiving such path quality data preferably will compare the received path quality data with respective stored path quality data and calculate a path quality correction value from a difference between the received and stored values, the path quality correction value being utilised to adjust the transmission power when transmitting data to the station which transmitted the path quality data.

The path quality correction factor may be calculated by deriving rate of change data from a plurality of path quality correction factor calculations.

The rate of change data may be utilised to adjust the transmission power predictively when transmitting data to a station whose path quality correction value is detected to be changing over time.

The method may include monitoring, from a station transmitting data, the background noise/interference at a station receiving a data transmission and adjusting the transmission power value at the station transmitting data to the receiving station, thereby to maintain the required signal to noise ratio at the receiving station.

The method may include adjusting the data rate of message data transmitted from a first station to a second station according to the transmission power

value set at the first station and the required signal to noise ratio at the second station.

The method may also include adjusting the length of message data packets transmitted from a first station to a second station according to the transmission power value set at the first station and the required signal to noise ratio at the second station.

Each station preferably monitors the transmissions of other stations to obtain path quality and background noise/interference data therefrom, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain path quality and background noise/interference data relating to the third station.

The method preferably includes selecting, opportunistically, a station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith.

Further according to the invention there is provided communication apparatus operable as a station in a network comprising a plurality of stations which can transmit data to and receive data from one another, the communication apparatus comprising:

transmitter means arranged to transmit data to selected stations;

receiver means arranged to receive data transmitted from other stations;

signal strength measuring means for measuring the power of received transmissions;

processor means for recording path quality data corresponding to the path quality associated with other stations; and

control means for adjusting the output power of the transmitter according to the path quality between the apparatus and a destination station.

The processor means is preferably arranged to calculate the path quality by comparing data in received transmissions relating to their transmission power and/or a previously measured path quality with the measurements made by the signal strength measuring means.

The processor means is preferably arranged to monitor at least one of the path loss, phase distortion, time delay, Doppler shift and multipath fading characteristics of a channel between the apparatus and other stations.

The processor means is preferably arranged to extract path quality data from received transmissions, to compare the path quality data with the measured power of received transmissions, and to calculate a path quality correction factor from the difference therebetween, the path quality correction factor being utilised by the control means to adjust the output power of the transmitter.

The processor means may be adapted to derive rate of change data from a plurality of path quality correction factor calculations, thereby to compensate for variations in the path quality between stations.

The processor means is preferably arranged to utilise the rate of change data to adjust the transmission power predictively when transmitting data to a station whose path quality correction value is detected to be changing over time.

Preferably, the processor means is arranged to store path quality data for each of a plurality of stations and to set an initial transmission power value when initiating communication with any of said plurality of stations according to the respective stored path quality data.

The processor means is preferably adapted to monitor transmissions of other stations to obtain path quality and background noise/interference data therefrom, so that the apparatus can select, opportunistically, another station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a multi-station communication network, indicating how an originating station can transmit data via a plurality of intermediate stations to a destination station;

Figures 2A to 2E comprise together a simplified flow diagram indicating graphically the operation of the method of the invention;

Figures 3 to 6 are schematic block diagrams of apparatus suitable for implementing the invention; and

Figures 7 to 9 are flow diagrams showing the power, modem data rate and packet size adaption processes of the invention, respectively.

SUBSTITUTE SHEET (RULE 26)

DESCRIPTION OF EMBODIMENTS

The network illustrated schematically in Figure 1 comprises a plurality of stations, each comprising a transceiver able to receive and transmit data from any other station within range. A communication network of this kind is described in international patent application no. WO 96/19887, the contents of which are incorporated herein by reference. The stations of the network maintain contact with one another using the probing methodology described in international patent application no. PCT/GB98/01651, the contents of which are also incorporated herein by reference.

Although the method and apparatus of the present invention were designed for use in the above referenced communication network, it should be understood that the application of the present invention is not limited to such a network

and can be employed in other networks, including conventional cellular or star networks, or even in a two-way communication situation between first and second stations.

In Figure 1, an originating station A is able to communicate with five "nearby" stations B to F, and is transmitting data to a destination station O via intermediate stations B, I and M.

When any of the stations transmit data to any other station, it is necessary that the transmit power used be sufficient to enable successful reception of the transmitted data at the receiving station. At the same time, to avoid unnecessary energy consumption and interference with other stations in the network, or other communications systems in general, it is desirable to minimise the transmission power utilised.

The problem of setting an optimum transmission power is complicated by variations in the path quality between stations, which may be severe in the case of stations which are moving relative to one another.

In this specification, the expression "path quality" includes path loss (also referred to by those skilled in the art as transmission loss or path attenuation) which is a measure of the power lost in transmitting a signal from one point to another through a particular medium. However, the expression also includes other parameters of the transmission path between any two stations, such as phase distortion, time delay spread, Doppler shift and multipath fading characteristics, which would affect the transmission power required for successful transmission between any two stations.

The present invention addresses this problem by providing a method and apparatus for continually monitoring the path quality between stations and adjusting the transmission power used when transmitting data, so as to use just enough power to ensure successful reception of the transmitted data, without transmitting at a higher power than is required. In addition, other transmission parameters, such as the equalisation and coding applied to the transmitted signals, can be adjusted to improve the likelihood of successful reception.

When a station receives a data package from a remote station it measures the power or strength of the received transmission. This is known as the Received Signal Strength Indicator (RSSI) value of the received transmission. In the data packet from the remote station there is included data corresponding to the transmission power used by the remote station. The local station can therefore calculate the path loss (ie. transmission loss or path attenuation) between the two stations by subtracting the locally measured RSSI value from the transmission power value in any data packet. Whenever a local station responds to a probe signal from a remote station, it will always indicate the path loss it has calculated in the response data packet. Likewise, the local station knows that any data packets addressed to itself will contain data corresponding to the path loss measured by the remote station from the most recent probe signal received by that remote station from the local station.

The local station will compare its calculated path loss with the path loss data received from the remote station, and will use the difference in the path loss values to determine a correction factor to use when transmitting data to the remote station, thereby to adapt its output power to an optimum level, or as

close to it as possible.

The first time the local station hears from the remote station it will use a correction factor of:

$Path_{Cor}$ = Remote Path Loss - Local Path Loss

Thereafter:

$Path_{Cor}$ = $Path_{Cor}$+(((Remote Path Loss - Local Path Loss)+$Path_{Cor}$)/2)-$Path_{Cor}$)

where the maximum adjustment made to $Path_{Cor}$ in both cases is 5 dB up or down.

$Path_{Cor}$ may only be a maximum of ± 30dB.

The local station adds the correction factor $Path_{Cor}$ to its measured path loss, thus generating a Corrected Path Loss value when determining what power to use when responding to the remote station. However, the Path Loss value it places in the packet header is its measured Path Loss without correction.

If the local station does not get a direct response from the remote station after ten transmissions then it must increase its $Path_{Cor}$ value by 5dB to a maximum of +10dB. The reason for doing this is to avoid going below the noise threshold of the remote station. (The $Path_{Cor}$ value is added to the measured

Path Loss. The adjusted Path Loss is then used to determine the required transmission power. A smaller value for $Path_{Cor}$ will correspond to a lower transmission power. Therefore, if the $Path_{Cor}$ value is made too small or even negative then the transmission power may be too low to reach the remote station. It is therefore necessary to increase the $Path_{Cor}$ value in 5dB steps until a response from the remote station is detected).

The local station will also not increase its transmission power more than 10dB above normal. This is to avoid swamping other stations if there is an error with the remote station's receiver. However, if the local station does receive a response then the maximum adjustment may go as high as 30dB above normal.

If the RSSI of the remote station is pegged it will set its Path Loss value in the data packet header as 0 (zero). A station will not make any adjustment to its path quality correction factor if either the remote Path Loss in the header is at zero, or if its local RSSI is pegged.

Having calculated the Path Loss and the correction factor $Path_{Cor}$, the local station can now determine the power required to transmit back to the remote station. The remote station also includes in every packet it sends the background RSSI values for the current, previous, and next modem. The local station will use the Corrected Path Loss and the remote background RSSI value to determine what power to use when responding.

Each station has a minimum Signal to Noise (S/N) ratio level that it will try to maintain for each modem. It is assumed that the required Signal to Noise ratio

of all the stations in the network is the same. The local station will set the power level for its transmissions such that the remote station will receive them at the correct S/N ratio. If the local station has additional data to send, or if it can operate at a higher data rate, then the required S/N ratio required may vary.

Example 1

Remote station Tx Power	: 40 dBm
Remote Station Background RSSI	: -120 dBm
Remote Station Path Loss	: 140 dB
Local station Required S/N	: 25 dB
Local station Path Loss	: 130 dB

$Path_{Cor}$ = Remote Path Loss - Local Path Loss
(Assume first time)
= 140 - 130
= 10 dB

Corrected Path Loss = Local Path Loss + $Path_{Cor}$
= 130 + 10
= 140 dB

Local Tx Power = Remote RSSI + Required S/N + Corrected Path Loss
= -120 + 25 + 140
= 45 dBm

From the above example it can be seen that the local station must use a Tx Power of 45 dBm to obtain a remote S/N ratio of 25 dB. If the local station can only set its power in 10 dB steps then it must adjust its power up to the next step, ie. 50 dBm.

The power adaption process described above is summarised graphically in the flow chart of Figure 7.

A station may have one or more modems. Each modem operates at a different data rate. However, they all operate in the same channel, ie. frequency and/or medium. Therefore when a station changes channels all the modems will be available on the new channel. A channel may however have a minimum and/or maximum data rate associated with it. For example if a station is on a 80 kbps probing channel it may not use data rates lower than 80 kbps. Therefore it may not use the 8 kbps modem on that channel. In the same way the 8 kbps probing channel may have a maximum bandwidth of 80 kbps, therefore not allowing the use of the 800 kbps modem on that channel.

When a station is probing on a probing channel, it will use the data rate associated with the channel. It will always probe on the channel and at the power required to maintain 5 neighbours.

When a local station responds to the probe of a remote station, or if it responds to a data packet of a remote station, it will always try to use the optimum modem for its response.

A station will always try to respond at the highest data rate possible. The highest data rate will be determined by the maximum data rate allowed for the channel and by, the remote S/N ratio on the modem associated with that data rate.

If a station can use a higher data rate on the channel, it will determine the remote S/N for that data rate. If it can achieve that required S/N ratio it will use the higher data rate. On the other hand, if the conditions are poor and the station can't achieve the required S/N ratio then it will remain at the current data rate. When condition are very poor and the station can't maintain the current data rate, it may even choose to respond at a lower data rate, if the channel allows. It will only use a lower data rate if the S/N ratio of the lower data rate is achieved. If the station cannot use a lower data rate, and if it is on the lowest data rate available then the station will try anyway. However, if there is a lower data rate available, but the station may not use it on the current channel, then the station will not respond to the remote station. This will force the remote station to find a lower data rate channel.

In summary:

- A station will switch to the next modem if the S/N ratio of the next modem meets the required S/N ratio and the maximum modem rate of the channel allows the next modem to be used.

- A station will switch to the previous modem if the S/N ratio of the current modem is below the required S/N ratio and the S/N ratio of the previous modem meets the required S/N ratio and

the minimum modem rate of the channel allows the previous modem to be used.

The modem data rate adaption process described above is summarised graphically in the flow chart of Figure 8.

When a station responds to another station it will always try to send as much data as it can. The factors which limit the packet size are: spacing between probes, maximum transmission power, and the allowed transmission duration on a data channel.

In the prototype system, the base packet size is 127 bytes. This is the smallest packet size that will allow data to be reliably transmitted between two stations. (This assumes there is data to send. If a station has no data to send then the packet will always be smaller than 127 bytes.)

A station will use the base packet size under very bad conditions even when it has more data to send. Thus if it is sending to a remote station which has bad background noise, or is very far away, it will only be able to respond at the lowest data rate (8 kbps), and at maximum power.

If a station can achieve a remote S/N ratio better than the base value (i.e. Required S/N for 8 kbps), it may start using larger packets based on the following equations:

For a 10x baud rate increase it will multiply the packet size by a factor

Z. (Typically Z = 4)

Multiplier for packet size = $Z^{\log(X)}$, where X is Baud 2 / Baud 1.

For a 10dB S/N increase, multiply packet size by Y (Typically Y = 2)

Multiplier for packet size = $Y^{W/10}$, where W is additional S/N available.

The values for Z and Y are fixed for the entire network. Typical values for Z and Y are 4 and 2 respectively.

Example 2

If a station can respond at 80 kbps at the required S/N ratio for 80 kbps, it will then use a maximum packet size of $127 * 4^{\log(80000/8000)} = 127 * 4 = 508$ bytes. If the station cannot fill the packet, it will still use the power required to achieve the required S/N ratio.

Example 3

If a station can respond at 15 dB above the required S/N ratio for 80 kbps, it will then use a maximum packet size of $127 * 4^{\log(80000/8000)} * 2^{15/10} = 127 * 4 * 2.83 = 1437$ bytes. If the station cannot fill the packet it will drop its transmission power to the level required for the packet size it will actually use. For example, even though it could use a packet size of 1437 bytes, if it only has 600 bytes to send to the other station it will adjust its Tx power to a level between the required S/N and 15dB above the required S/N by using the inverse of the equation $Y^{W/10}$ to determine how much additional power it

needs above the required S/N ratio.

It is important to note that even though a station may use a larger packet size based on the available S/N ratio and data rate, the packet size may be limited by the probe interval. For example, if the probe interval on the 8 kbps channel is 300 milliseconds, and the maximum packet size based on the available S/N ratio is 600 bytes (which translates to 600 milliseconds at 8 kbps), it can be seen that a packet size of less than 300 bytes must be used, otherwise other stations may corrupt the packet when they probe.

A number of factors must be taken into account when trying to determine the maximum packet size based on the probing rate. These factors include: Tx on delay (the time for the transmitter power amplifier to settle, and for the remote receiver to settle), modem training delay (length of modem training sequence), turnaround delay (time for processor to switch from Rx to Tx, ie. to process data), and propagation delay (time for signal to travel through medium).

To determine the maximum packet size based on the probing rate the following equation is used:

Max Length (ms) = Probe interval - Tx on delay - modem training delay - turnaround delay - propagation delay

The length in bytes can then be determined by:

Max Length (bytes) = Data Rate / 8 * Max Length (seconds)

Example 4

Probe interval is 300 milliseconds on 8 kbps channel. Tx on delay 2 milliseconds, modem training delay is 2 milliseconds, turnaround delay 3 milliseconds, propagation delay 8 milliseconds (worse case for station 1200 km away).

Max Length (ms) = Probe interval - Tx on delay - modem training delay - turnaround delay -propagation delay
= 300 - 2 - 2 - 3 - 8
= 285 ms

Max Length (bytes) = Data Rate / 8 * Max Length (seconds)
= 8000 / 8 * 0.285
= 285 bytes

The packet size adaption process described above is summarised graphically in the flow chart of Figure 9.

Below is a table giving details of the format of Probe and Data packets used in the network of the invention.

Format of Probe and Data packets

Variable	Bit Len	Allows
Preamble	64	Modem training sequence (101010101010 etc ...)
Sync1	8	First Sync Character used to lock Zilog
Sync2	8	Second Sync Character used to lock Zilog
Sync3	8	Third Sync character checked by software
Packet Size	16	Size of packet from Sync3 until last CRC
Size Check	8	Packet Size Check = Packet Size MSB XOR LSB
Protocol Version	8	Protocol Version
Packet Type	8	Packet Type (E.g. Probe, Data, Key, etc.)
Sending ID	32	Sending Station ID
Receiving ID	32	Receiving Station ID (0 = Broadcast)
Packet Number	16	Packet number
Adp Tx Power	8	Sending station current power in dBm
Adp Tx Path Loss	8	Path Loss measured at sending station in dB
Adp Tx Activity	4	Sending station current Activity Level
Adp Tx Antenna	8	Sending station current antenna configuration
Adp Tx Bkg RSSI -1	8	Sending station RSSI in dBm -> Current Modem -1
Adp Tx Bkg RSSI	8	Sending station RSSI in dBm -> Current Modem
Adp Tx Bkg RSSI +1	8	Sending station RSSI in dBm -> Current Modem +1
Adp Tx Spike Noise	8	Spike Frequency & Level at sending station
Adp Rx Activity	4	Required Activity Level for receiving station
Adp Rx Channel	8	Required Rx & Tx Channel for receiving station
Header CRC	16	16 bit CRC for header data
Neigh Routing Flags	8	Bit 0 - In Traffic, Bit 1 - Gateway, Bit 2 - Cert Auth
Neighbour Data Size	16	Size of routing data in bytes = 3 + 4 (Update) + IDs * 6
Neigh Soft Update	32	Software Update Version (16) and Block Number (16)
Neighbour Data	x	Neigh * (32 (ID) + 8 (TxPowerReq) + 4 (ModemReq) + 4 (Flags))
Packet Data	x	
CRC	32	32 bit CRC for whole packet, including header

Preamble:

This is a modem training sequence consisting of alternating 1's and 0's.

Sync1 – Sync3:

These are the three Sync characters that are used to detect the start of a

valid packet.

Packet Size:

This is the total size of the packet from Sync3 up to and including the last CRC byte. The maximum packet size that is allowed on a probing channel is determined by the probing rate, ie. a station may not send a packet that is longer (measured in time) than the spacing between probes on the probing channel. The maximum packet size that is allowed on a data channel is determined by the amount of time a station is allowed to remain on a data channel.

Size Check:

This is used to check the Packet Size variable to avoid any invalid long packet receptions.

Protocol Version:

This is used to check which protocol version is being used. If the software can not support the version the packet will be ignored.

Packet Type:

This defines the type of packet being sent. Another packet will directly follow the current packet, if the most significant bit is set.

Receiving ID:

This is the ID of the station to which the packet is addressed.

Sending ID:

This is the ID of the station currently sending the packet.

Packet Number:

Each packet that is transmitted is given a new sequential number. The number is not used in any way by the protocol. It is merely there to provide information to a systems engineer. Each time the station is reset, the packet number starts at a random number. This prevents confusion with older packets.

Adp Tx Power:

The sending station's current power is given as the absolute power in dBm, in the range -80dBm to +70dBm. (Field allows values from -128 dBm to +127 dBm)

Tx Path Loss:

This is the path quality as measured at the sending station. Path Loss = (Remote Tx Power - Local RSSI) of receiving station's previous transmission. A value of 0 is used to indicate that the sending station's RSSI was pegged. The Path Quality is used as a correction factor at

the receiving station, for the next time the receiving station transmits to the sending station.

Adp Tx Activity:

This is the activity level of the sending station, measured as: Activity = Watts * Time / (Bandwidth * Success) averaged over time.

Adp Tx Antenna:

This indicates the current antenna configuration being used by the sending station. Each of the 255 possible configurations describes a complete antenna system, i.e. Tx and Rx antenna.

Adp Tx Bkg RSSI:

This is the current background RSSI at the sending station for the modem that it is currently transmitting on. It allows for values from -255 to -1 dBm. The value sent is the absolute value of the RSSI, and the receiving station must multiply the value with -1 to get the correct value in dBm. A value of 0 is used to indicate that the channel is not available or is greater than or equal to 0 dBm. A value of 0 dBm cannot be used for adaptation purposes.

Adp Tx Bkg RSSI –1:

Same as above except for the previous modem.

Adp Tx Bkg RSSI +1:

Same as above except for the next modem.

Tx Spike Noise:

The lower 3 bits for spike frequency in Hz, 0 = none, 1,5,10,50,100,500, & > 500, and the next 5 bits for spike amplitude in dB.

Adp Rx Activity:

If a station has a high activity level and is interfering with other stations, they will use this field to force the active station to drop its activity level. If a number of stations request a drop in activity then the interfering station will respond and drop its activity. If no stations request that such a drop, the active station will slowly start to increase its activity level. Thus if a station is in a very remote area it will keep increasing it activity level trying to generate connectivity. If it is in a very busy area, other stations will keep its activity at a lower level.

In preferred embodiments of the invention, a station will always try to maintain five neighbours, so that other stations should not need to request that the station reduce its activity. However the feature has been provided for cases where stations cannot reduce their power, or increase their data rate any further, yet they still interfere with too

many other stations.

Adp Rx Channel:

Allows 255 predefined channels. These channels are set for the entire network. Each channel will have a probing rate associated with it (it may be turned off, which makes it a data channel). Each channel will also have a minimum data rate associated with it. The channels will have the Tx and Tx Frequencies defined. The channels may also be defined as other media, e.g. Satellite, Diginet, ISDN, etc.

A sending station will request that another station move to a data channel (ie. where probing has been disabled) when it has more data to send to the receiving station than can fit in the packet size allowed for the probing channel.

Header CRC:

This is a 16-bit CRC check for the header data. It is the sum of all the bytes in the header. It is only checked if the packet CRC fails. This is provided as a means of determining which station sent the packet. If the packet CRC fails and the header CRC passes, the data provided in the header should be used with caution, since the Header CRC is not a very strong means of error detection.

The Neighbour routing fields given below are not included in the Header CRC since they may not be used unless the packet CRC is

passed. This makes the routing less prone to errors.

Neigh Routing Flags:

These flags are used to enhance routing. They provide additional information about the current station. Currently defined bits are:

Bit 0 – Set if current station is busy in traffic.

Bit 1 - Set if current station is an Internet Gateway.

Bit 2 – Set if current station is Certification Authority.

Bit 3 – Reserved.

Another byte of 8 bits could be added should more flags be required.

Neighbour Data Size:

Size of routing data in bytes. This includes the Neigh Routing Flags and Neighbour Data Size (ie. 3 bytes). Another 4 bytes are added if the Neigh Soft Update field is included. An additional 6 bytes are added for each neighbour included in the Neighbour Data section. Neigh Soft Update must be included if any Neighbour Data is included.

Neigh Soft Update:

This is the current version of update software available at the current station (Upper 16 bits of field) and the current block number available (Lower 16 bits of field).

Neighbour Data:

This is the list of neighbours that the current station has routing data for. Every time the current station receives updated routing data for a station that is better than the data it had, it will update its own data and include the station in this list in its next probe. The data section has four sub fields for each station in the list:

Station ID: 32 bit field with the ID of the neighbour station.

Tx Power Req: 8 bit field indicating the combined or direct Tx power required to reach the Station ID from the current station.

Modem Req: Modem required by current station to reach destination station.

Flags: Flags giving additional routing information for destination station. Bit 0 – In Traffic, Bit 1 – Gateway, Bit 3 – Cert Auth, Bit 4 – Direct Neighbour. The last bit indicates that the station in the list is a direct neighbour of the current station.

Packet Data:

This is the data of the packet. It is made up of 1 or more segments. The segments may be of any type, and may have originated or be destined for any ID.

CRC:

This is a 32 bit CRC check for the entire packet. If this CRC fails the packet data is discarded, however the header data may still be salvaged if the header CRC passes.

Enhanced method

The flow diagram of Figures 2A to 2D shows the process of measurement and power control and calibration carried out in the network of Figure 1. The originating station A measures the signal strength it receives from station B. In addition, station A identifies station B from its transmission headers and identifies which station it is addressing and what information is being sent. Station A then reads the transmit power and noise/interference level embedded in station B's header, thereby deriving from it the power level that Station B is using to reach the station it is addressing as well as its local noise/interference floor. Station A can then compute the path quality from station B to station A by using its measured signal strength and the declared power level of station B.

If station B is responding to another station such as station C, station A can read from station B's header its declared path quality to station C, thereby deriving information as to fluctuating path qualities between stations B and C , by simply monitoring the transmission of station B. In addition, since station B declares its transmitted power in responding to station C in conjunction with the path loss declared by station B to station C, it is possible for station A to compute the noise/interference floor at station C even though it cannot hear the transmissions of station C.

By monitoring the transmissions of station B at station A when station B transmits to station C, the path quality, required power level and noise/interference floor of both stations B and C may be derived, even though station C is "out of range" of station A.

If station B is probing and is not responding to any other station, no other information as to path quality or required path quality can be derived from its transmissions apart from calculating the effective path quality from A to B. If station A monitors station B responding to station A and reads the calculated path quality to station A embedded in station B's header, station A can then compare this calculated path quality to that read from station B and calculates a differential. Station A uses the differential to update its average path quality differential. This is done by comparing the path quality it computes to that which station B computes, and that differential is as a result of differences in the methods of measurement and other inaccuracies of the two stations.

However, since there is a fluctuation in path quality between transmissions it is possible that the path quality changes from the time that station B calculated the path quality from station A to station B, to the time that station A calculated the path quality from station B to station A. Therefore, a rate of change can be calculated over and above the differential long-term averaging which is a result of measurement inaccuracy. This rate of change will be due to the rate of change of the actual path quality due to propagation changes between transmissions.

Station A may also use a noise/interference level declared by station B to update its database to indicate the slow rate of change of noise/interference, based upon past records at station B and also fast fluctuations that may be in the noise/interference floor of B. Station A may then use the predicted fluctuations in the path quality from station A to station B and the predicted fluctuations in the rate of change of noise/interference in order to predict an opportunity to transmit to station B. This is done so as to choose periods of minimum path quality or minimum noise floor between stations A and B. Since station A is gathering data from other stations, for example stations B, C, D, E and F, it can decide whether station B provides the best opportunity, or whether it should choose one of the other stations. In addition, it can choose its data rate, packet duration and transmitter power based upon the rate of change and duration of the fluctuations of path quality and noise/interference that exist between stations A and B.

If station A chooses station B to transmit data to, it receives an acknowledgement back from station B, and the information is then forwarded on from station B opportunistically to the other stations. It is important to note that by monitoring the transmissions from station B, station A also has an idea of the path quality from station B to stations G, H, I, J, K, etc., and other stations to which station B can transmit. By monitoring those transmissions, it picks up the fluctuations in path quality between station B and the other stations and an indication of the noise/interference floor fluctuations of the other stations even if those other stations are not directly monitored by station A. Using this technique an opportunistic relay station can be chosen, taking not just the first hop but two hops into account and, providing overall routing information is

available, data can be routed effectively towards the destination station O.

Hardware

Figures 3, 4, 5 and 6 show the basic hardware used to implement the invention. These Figures correspond to Figures 8, 9, 10 and 11 of the abovementioned international patent application no. WO 96/19887.

Based upon its "decision" to transmit, the main processor 149 will decide on a power level data rate and packet duration to use and will send this packet to the serial controller 131 and simultaneously through the peripheral interface 147 switch the transmit/receive switch 103 into transmit mode and switch the transmitter on after a suitable delay. The Zilog chip 131 will send the packet data together with a suitable header and CRC check via the PN sequence encoders in block 128 or 130, depending on the data rate chosen.

The main processor 149 will embed in the data packet, as one of the fields of information, data corresponding to the transmit power it is using, which will be the same transmit power as sent to the power control PIC block 132, which in turn is used to drive the power control circuit 141, which in turn controls the gain control and low pass filter block 143. This block in turn uses feedback from the power amplifier 145 to control the drivers 144 and 142.

The sensing and gain feedback method allows a reasonably accurate power level to be derived based upon the instruction from the power control circuit 141.

Prior to switching the power amplifier on, the transmission frequency is selected by the synthesizer 138, after which the power amplifier 145 is instructed via the driver block 141 and the amplifier is switched on.

If power levels below the minimum power level provided by the power amplifier 145 are required, the switched attenuator block 102 may be switched in, in order to provide up to an additional 40 dB of attenuation. Therefore the processor can instruct the power amplifier to switch in an attenuator combination to provide an output power level ranging from minus 40 dBm to plus 50 dBm. When the amplifier is switched on, the processor obtains information from the low power sensing circuit 101 as to the forward and reverse power, which is sent via the analogue to digital converter 146 and is used by the main processor 149 in order to monitor the level of power being transmitted. This information is then stored in the dynamic RAM 150 to provide information as to forward and reflected power levels actually generated by comparison to the level requested.

The amount of output transmit power will be affected by the efficiency of the transmit power control loop (blocks 145, 144, 142 and 143) and the switched attenuator block 102. In addition, any mismatch in the antenna 100 will also result in variations in reflected and forward power. The relative power actually output for various levels required can be stored by the processor in the RAM providing a table giving requested against actual power output levels. This can be used to allow the processor to use a more accurate power level field in the information it provides on future transmissions, within messages or probe signals. Since the power level is varied from between minus 40 dBm to plus 50 dBm there are effectively ten different power levels spaced 10 dB

apart that may be transmitted. Therefore, the table stored by the processor will have these ten power levels, with the requested power level and actual power level being in this range.

Any other station in the network will then receive this transmission via its antenna 100. The received signal will then pass through the low power sensing circuit 101 and the switched attenuator 102, which initially is set for 0 dB attenuation. It will then pass through the 2 MHz bandpass filter 104, which will remove out of band interference, and then passes into the preamplifier 105, which amplifies the signal before it is mixed down via the mixer 106 to a 10.7 MHz IF signal. This signal is filtered by the bandpass filler 107, and amplified in the IF amplifier 108 and further filtered and amplified in blocks 109, 110. 111 and 112.

The final filtering occurs at blocks 114 and 115, at which stage the signal is measured at block 116 using the narrowband RSSI function, the output of which is used via the main processor to determine the signal strength of the incoming transmission. This then allows the processor, if necessary, to request the power control PIC circuit 132 to switch in additional receiver attenuation up to 40 dB. The switching in of additional attenuation in will only be necessary if the signal exceeds the measurement range of the NE615 of block 116. Otherwise, the attenuator is left at 0 dB attenuation, allowing the full sensitivity of the receiver to be available for receiving small signals. The incoming transmission is measured in two bandwidths simultaneously, namely 8 kHz and 80 kHz. The 80 kHz bandwidth is measured by tapping off the 10.7 MHz IF signal after the 150 kHz ceramic filter 109 and using a 150 kHz ceramic filter 121 and an NE604 IC 120. This, too, has an RSSI output

which is received via the interface by the main processor 149.

The broadband and narrowband RSSI are measured via the analogue to digital converter 146, which then passes the data on to the main processor 149. The main processor has a lookup table, and takes the information from the A to D converter and derives from previously calibrated data a receive signal strength. This data is calibrated in dBm, typically from minus 140 dBm to 0 dBm. This information is typically generated using the output of a calibrated signal generator, injecting this into the input of the receiver, and then dialling up various signal strength levels and instructing the processor via the keyboard 209 as to what power levels are being injected. This information is then stored permanently in static RAM or flash RAM 150.

Therefore, the receiving station can accurately record the power level of any incoming transmission. It then reads the address of the incoming transmission and its embedded transmit power level. By comparing these, for example, a plus 40 dBm transmit power level may be measured in the receiver as minus 90 dBm and this is then used to compute a path loss of 130 dB. Path losses may vary from 0 dB up to a maximum of 190 dB (+50 - (-140) = 190). The minimum path loss that can be measured is dependent on the transmission power of the transmitting station and the maximum signal that can be measured by the receiving station. Since with this design the maximum receiving signal is 0 dBm at the antenna port 100, a 0 dB path loss can be measured, providing the transmit power is less than 0 dBm. Otherwise, for example, at a transmit power of 50 dBm the minimum path loss that can be measured is 50 dB. This could be improved by adding additional steps in the switched attenuator or through using a different arrangement in the receiver. If

the switched attenuator is fully switched in and the output of the A to D converter indicates that the RSSI is at its highest level, the receiving processor will tag the data associated with the transmission as being "pegged". This means that the path loss is less than is measurable.

The processor on receive will continually measure the background signal and interference, and providing that no transmissions are detected on either modem at either data rate, will monitor and measure the noise and interference in dBm and generate an average which will be stored in the static RAM. When a transmission is detected, the most recent noise measurement is compared to the signal strength to derive a signal to noise ratio. On each transmission, the background noise picked up prior to transmission is advertised inside the transmission message or probe as another field together with the transmitted power. Other stations in the network can pick up and derive from transmission not only the path quality but also the distant station's noise floor just prior to its transmission. The receiving station, since it knows the path quality and has the noise floor of the distant station, will then know at what power to transmit to achieve any desired signal to noise ratio at the distant station.

The required signal to noise ratio is typically based upon the performance of the modem and a figure based upon packet duration and probability of success. This required signal to noise ratio is stored in the database by the processor and is continually updated, based upon the success of transmissions to various destinations. If a station, for example, picks up a transmission and calculates the path loss to be 100 dB and the distant station to have a declared noise floor of minus 120 dBm, to meet the required signal to noise ratio of for

example, 20 dB for 8 kilobits per second, it will then transmit at a power level of minus 20 dBm. This required signal to noise ratio will be different for 80 kilobits per second in that the noise floor would be higher in the wider bandwidth of 150 kHz by comparison to 15kHz and in that the performance of the 80 kilobits per second modem may be different from that of the 8 kilobits per second modem.

Therefore, the receiving station would know that if, for example, the declared noise floor in the wideband is minus 110 dBm and the path loss is still 100 dB, but the required signal to noise ratio is, for example, 15 dB, it would require a transmission power of plus 5 dBm. The station receiving the transmission will know what power level to use to respond to the originating station.

Monitoring other communicating stations, the receiving station will see the path quality variation and the noise floor declared by various other stations it is monitoring varying as well, and through choosing a moment of minimum path quality and minimum noise floor will transmit at the appropriate power level to achieve the required signal to noise ratio to the station or stations that it is monitoring. In responding to a transmission, the responding station will switch on its transmitter, control the power amplifier via the power control PIC 132 to meet the required power level and then the main processor 149 will embed the fields of its own transmit power, its own receive noise prior to transmission and the path quality that it has just received from the station to which it is responding.

Depending on the signal to noise ratio and the power level required, the main

processor will elect to switch in either the 80 kilobit per second or 8 kilobit per second modem and make the transmission. On making this transmission, it will embed its own transmit power level, its own background noise floor measured in both the 150 kHz and 15 kHz bandwidth and the path quality it has just calculated for the transmission to which it is responding. The originating station, on receiving the transmission, will again measure the RSSI in the two bandwidths and via the A to D converter 146, and using the lookup table in the static RAM 150, calculate the received signal strength. By examining the received packet passed from the Zilog synchronous serial chip 131, it will calculate the received path loss using the transmitter power declared and the measured RSSI and compare the path loss value sent to it by the other station.

In comparing these two path losses, since only a short period of time has elapsed between transmission and reception, these two path losses should be quite similar unless the path loss is fluctuating, caused perhaps by a moving vehicle environment. In successive transmissions, the difference between the two path loss values is averaged and stored since this number represents the difference due to measurement error in signal strength or error in the declared power level being transmitted. The averaging process is used to average out, say, the effects of moving vehicles and path loss fluctuation. The main processor will use this averaged number and retain one for every station in the network. It will have a path loss correction factor or delta ranging from a few dB to tens of dB for each station in the network which it will store in RAM. On detecting any station transmitting and measuring the path loss, the correction factor is then used to correct the transmit power level before responding to the station, ie. predictively . A typical process is as follows:

Station A measures the incoming path loss from Station B, of say 100 dB. Station A looks at Station B's address which is then compared to a lookup table to determine a correction factor or delta, for example 10 dB plus. This means that the path loss as measured by Station A is on average 10 dB higher than that measured by Station B. Based upon the path loss just measured by Station A and Station B's, noise, the power level required is calculated by Station A to meet the required signal to noise ratio at Station B. The difference allowed between the declared path loss by Station B and the measured path loss by Station A is stored by Station A. If a strong variation is detected, this is in all probability due to fluctuating path loss between transmissions, and therefore the receive signal strength is used to determine the path loss by Station A. The difference between the path loss values is used to update the average differential number, which over a number of transmissions will average any fluctuations in path loss between transmission and response.

Having the differential number is also useful, in that on hearing a station probing or communicating to any other station, a path loss can be calculated using the correction factor and an estimation can be made of the required transmit power to use to reach the distant station with sufficient signal to noise ratio. The path loss delta or correction factor is only updated when stations are interacting with each other and this field will only be present in a transmission when a station is responding to another, and will not be present when another station is simply probing, when this field is left empty.

Although embodiments of the invention have been described above with specific reference to the measurement of path loss in the sense of path attenuation or transmission loss, it will be understood that additional path quality parameters such as those referred to above can be measured to provide a more accurate path quality value for use in adjusting the transmission power used when transmitting data between stations.

CLAIMS:

1. A method of operating a communication network comprising a plurality of stations able to transmit data to and receive data from one another, the method comprising:

monitoring, at each station, the path quality between that station and each other station with which that station communicates;

recording, at each station, path quality data corresponding to the path quality associated with each said other station;

setting, at each station, a transmission power value based on the recorded path quality data associated with a selected other station when transmitting data to said selected other station, thereby to increase the probability of transmitting data to said selected other station at an optimum power level; and

transmitting path quality data corresponding to the path quality between a first and a second station when transmitting other data between the stations, so that path quality data recorded at the first station is communicated to the second station for use by the second station and vice versa.

2. A method according to claim 1 wherein the monitoring of path quality between stations includes monitoring at least one of the path loss, phase distortion, time delay, Doppler shift and multipath fading characteristics of a channel between the stations.

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3. A method according to claim 1 or claim 2 wherein the path quality at a station receiving a data transmission is calculated by comparing the measured power of the received transmission with data in the transmission indicating the transmission power thereof.

4. A method according to claim 3 wherein a station receiving such path quality data compares the received path quality data with respective stored path quality data and calculates a path quality correction value from a difference between the received and stored values, the path quality correction value being utilised to adjust the transmission power when transmitting data to the station which transmitted the path quality data.

5. A method according to claim 4 wherein the path quality correction factor is calculated by deriving rate of change data from a plurality of path quality correction factor calculations.

6. A method according to claim 5 wherein the rate of change data is utilised to adjust the transmission power predictively when transmitting data to a station whose path quality correction value is detected to be changing over time.

7. A method according to any one of claims 1 to 6 wherein each station monitors the transmissions of other stations to obtain path quality data therefrom, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain path quality data relating to the third station.

8. A method according to any one of claims 3 to 7 including monitoring, from a first station transmitting data, the background

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noise/interference at a second station receiving a data transmission and adjusting the transmission power value at the station transmitting data to the receiving station, thereby to maintain the required signal to noise ratio at the receiving station.

9. A method according to claim 8 wherein each station includes local background noise/interference data in at least some of its transmissions to other stations, for use by the other stations in adjusting their transmission power values when transmitting data to said each station.

10. A method according to claim 8 or claim 9 including adjusting the data rate of message data transmitted from a first station to a second station according to the transmission power value set at the first station and the required signal to noise ratio at the second station.

11. A method according to any one of claims 8 to 10 including adjusting the length of message data packets transmitted from a first station to a second station according to the transmission power value set at the first station and the required signal to noise ratio at the second station.

12. A method according to any one of claims 1 to 11 wherein each station monitors the transmissions of other stations to obtain background noise/interference data therefrom, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain background noise/interference data relating to the third station.

13. A method according to any one of claims 1 to 12 including selecting, opportunistically, a station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith.

14. Communication apparatus operable as a station in a network comprising a plurality of stations which can transmit data to and receive data from one another, the communication apparatus comprising:

transmitter means arranged to transmit data to selected stations;

receiver means arranged to receive data transmitted from other stations;

signal strength measuring means for measuring the power of received transmissions;

processor means for calculating and recording path quality data corresponding to the path quality associated with other stations; and

control means for adjusting the output power of the transmitter according to the path quality between the apparatus and a destination station,

wherein the processor means is arranged to include the path quality data in its transmissions to other stations for use by them, and to receive path quality data in transmissions from other stations for use in calculating updated path quality data.

15. Communication apparatus according to claim 14 wherein the processor means is arranged to calculate the path quality by comparing data in received transmissions relating to their transmission power

and/or a previously measured path quality with the measurements made by the signal strength measuring means.

16. Communication apparatus according to claim 15 wherein the processor means is arranged to monitor at least one of the path loss, phase distortion, time delay, Doppler shift and multipath fading characteristics of a channel between the apparatus and other stations.

17. Communication apparatus according to claim 15 or claim 16 wherein the processor means is arranged to extract path quality data from received transmissions, to compare the path quality data with the measured power of received transmissions, and to calculate a path quality correction factor from the difference therebetween, the path quality correction factor being utilised by the control means to adjust the output power of the transmitter.

18. Communication apparatus according to claim 17 wherein the processor means is adapted to derive rate of change data from a plurality of path quality correction factor calculations, thereby to compensate for variations in the path quality between stations.

19. Communication apparatus according to claim 18 wherein the processor means is arranged to utilise the rate of change data to adjust the transmission power predictively when transmitting data to a station whose path quality correction value is detected to be changing over time.

20. Communication apparatus according to any one of claims 14 to 19 wherein the processor means is arranged to monitor path quality data in transmissions from other stations, so that a first station monitoring a transmission from a second station within range of the first station to a

AMENDED SHEET

third station out of range of the first station can obtain path quality data relating to the third station.

21. Communication apparatus according to any one of claims 18 to 20 wherein the processor means is arranged to store path quality data for each of a plurality of stations and to set an initial transmission power value when initiating communication with any of said plurality of stations according to the respective stored path quality data.

22. Communication apparatus according to any one of claims 14 to 20 wherein the processor means is arranged to monitor background noise/interference data in transmissions from other stations, so that a first station monitoring a transmission from a second station within range of the first station to a third station out of range of the first station can obtain background noise/interference data relating to the third station.

23. Communication apparatus according to any one of claims 14 to 22 wherein the processor means is adapted to select, opportunistically, another station for transmission of data thereto according to the path quality and/or background noise/interference data associated therewith.

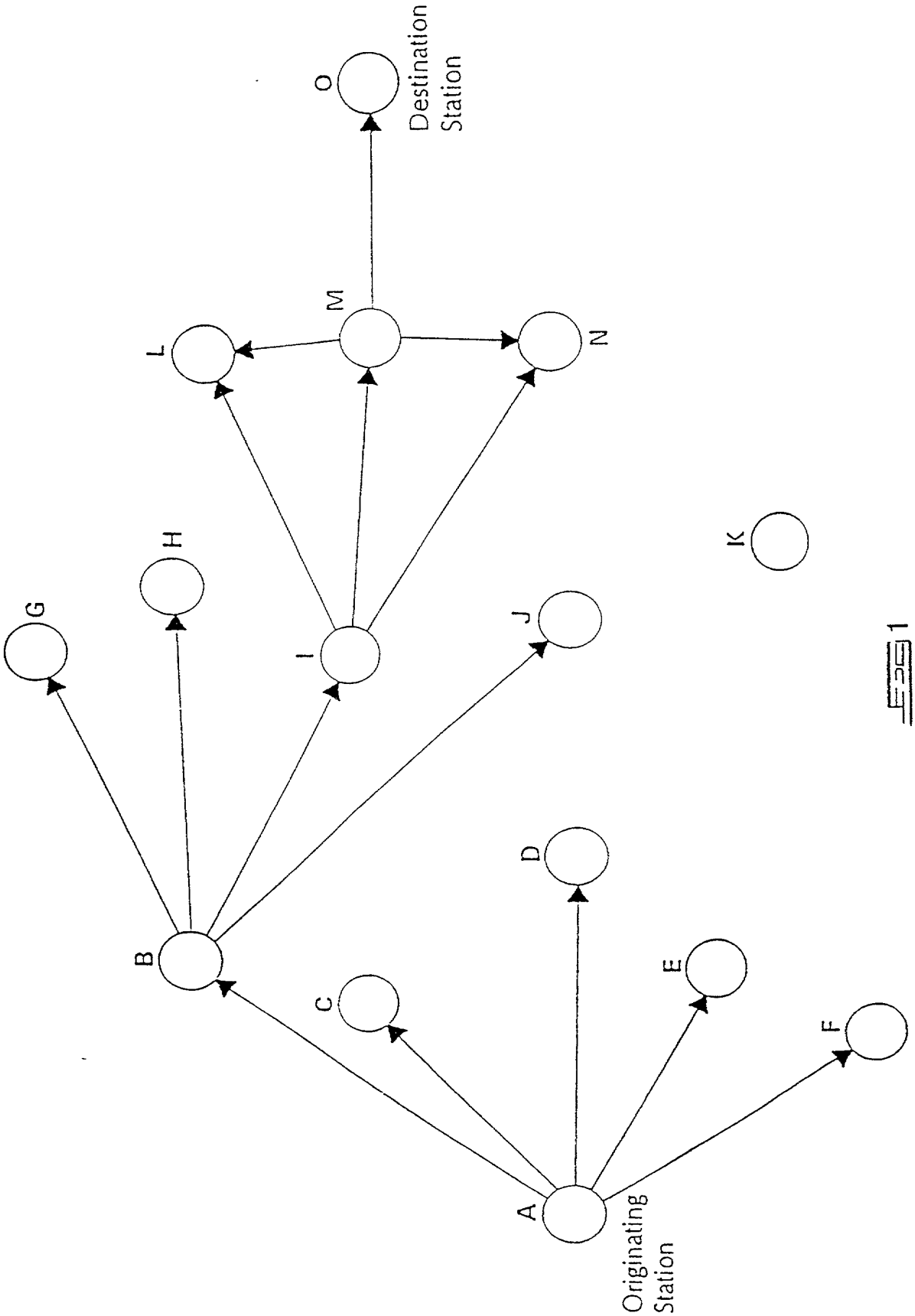


Fig 1

SUBSTITUTE SHEET (RULE 26)

Fig 2A

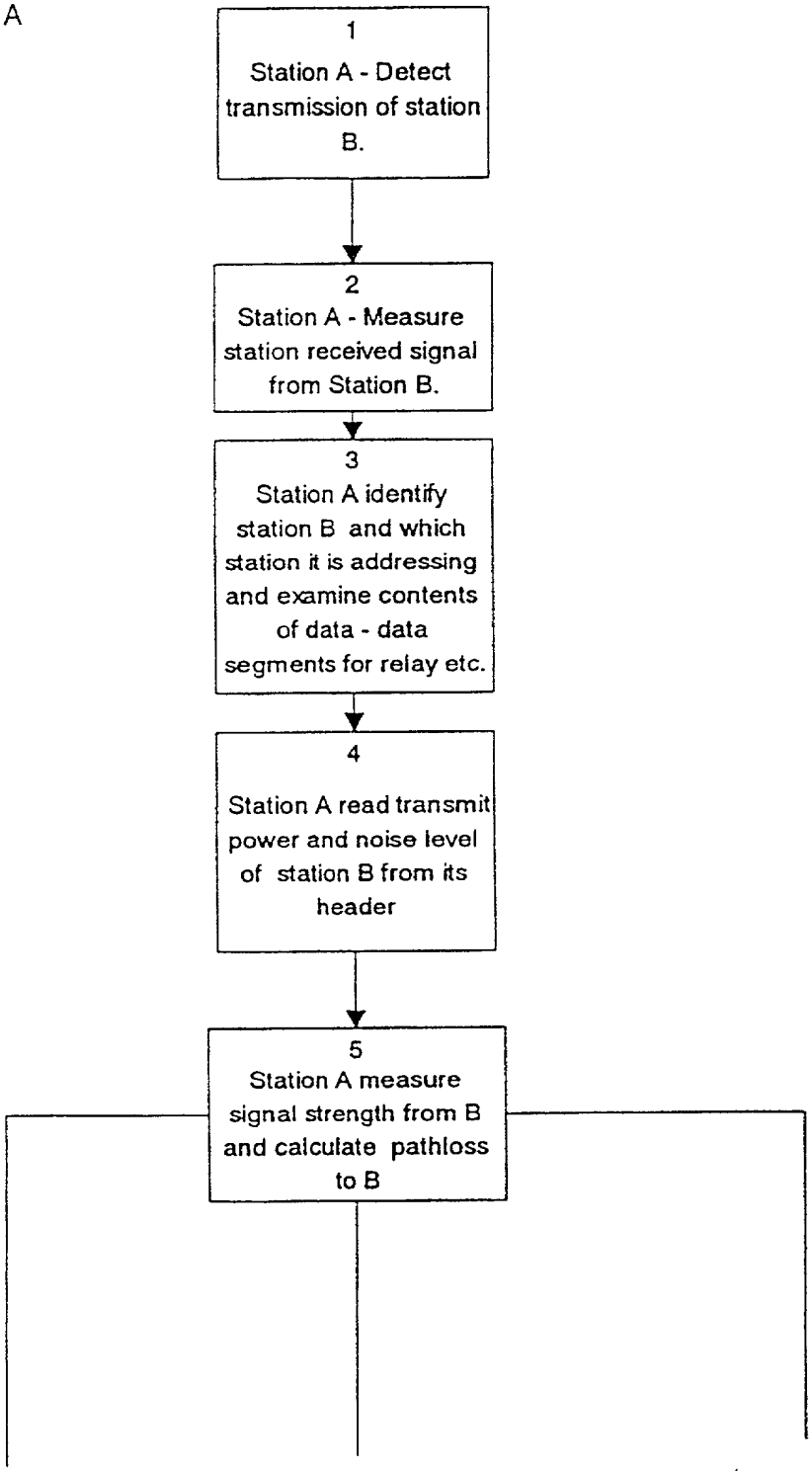
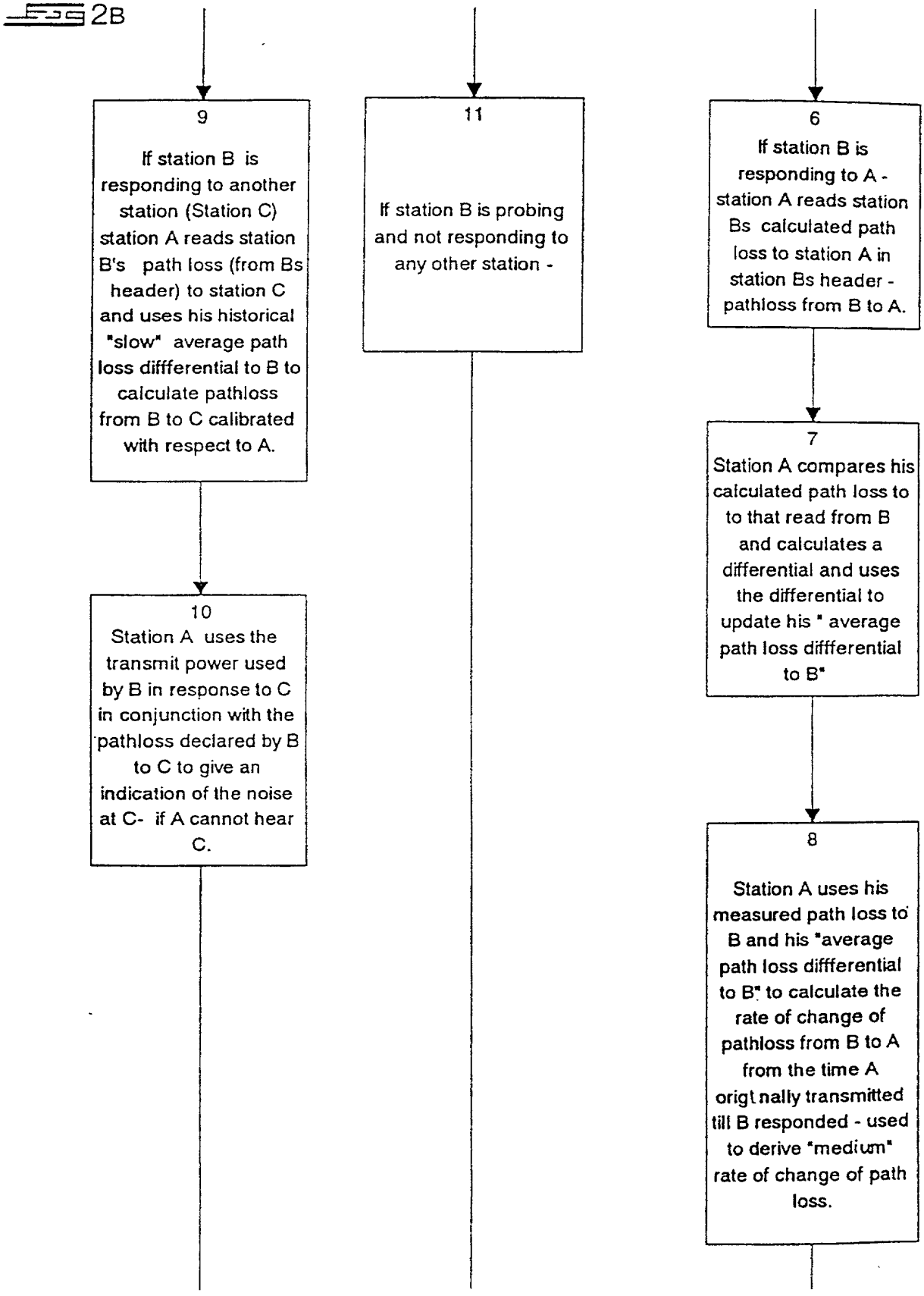

1
Station A - Detect transmission of station B.
2
Station A - Measure station received signal from Station B.
3
Station A identify station B and which station it is addressing and examine contents of data - data segments for relay etc.
4
Station A read transmit power and noise level of station B from its header
5
Station A measure signal strength from B and calculate pathloss to B

FIG 2B


9
If station B is responding to another station (Station C) station A reads station B's path loss (from Bs header) to station C and uses his historical "slow" average path loss diffferential to B to calculate pathloss from B to C calibrated with respect to A.
10
Station A uses the transmit power used by B in response to C in conjunction with the pathloss declared by B to C to give an indication of the noise at C- if A cannot hear C.
11
If station B is probing and not responding to any other station -
6
If station B is responding to A - station A reads station Bs calculated path loss to station A in station Bs header - pathloss from B to A.
7
Station A compares his calculated path loss to to that read from B and calculates a differential and uses the differential to update his " average path loss diffferential to B"
8
Station A uses his measured path loss to B and his "average path loss diffferential to B" to calculate the rate of change of pathloss from B to A from the time A orig t nally transmitted till B responded - used to derive "medium" rate of change of path loss.

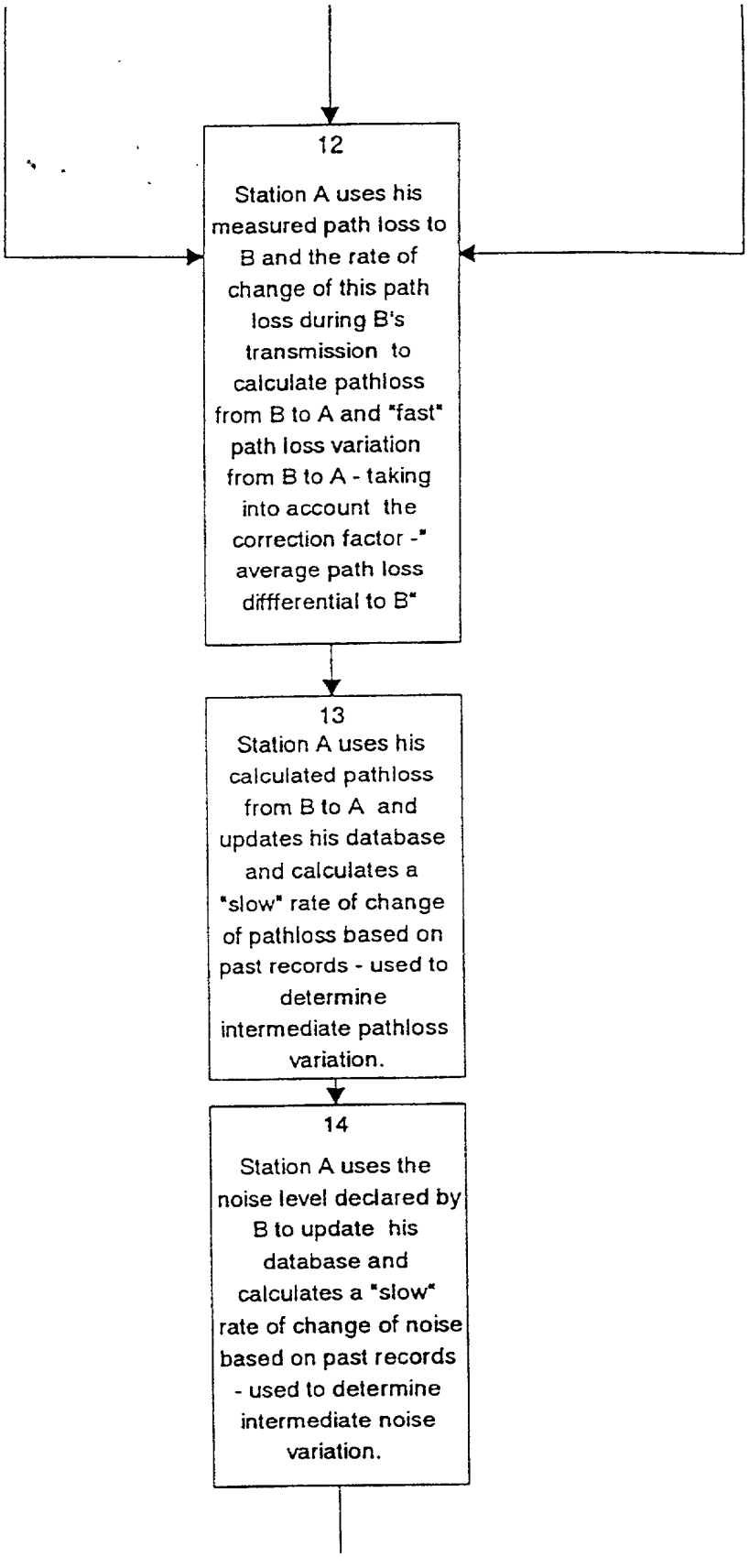

12
Station A uses his measured path loss to B and the rate of change of this path loss during B's transmission to calculate pathloss from B to A and "fast" path loss variation from B to A - taking into account the correction factor -" average path loss diffferential to B"
13
Station A uses his calculated pathloss from B to A and updates his database and calculates a "slow" rate of change of pathloss based on past records - used to determine intermediate pathloss variation.
14
Station A uses the noise level declared by B to update his database and calculates a "slow" rate of change of noise based on past records - used to determine intermediate noise variation.

Fig 2c

Fig 2D

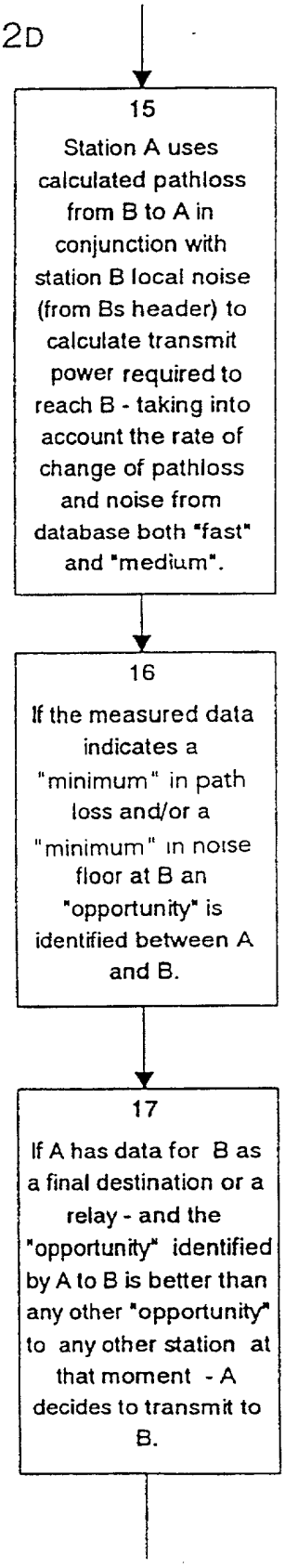
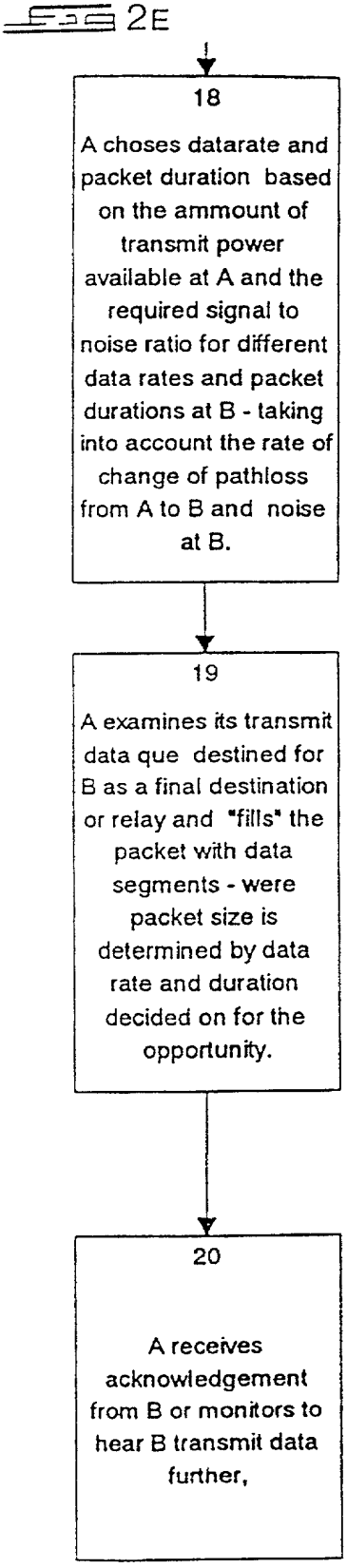

15
Station A uses calculated pathloss from B to A in conjunction with station B local noise (from Bs header) to calculate transmit power required to reach B - taking into account the rate of change of pathloss and noise from database both "fast" and "medium".
16
If the measured data indicates a "minimum" in path loss and/or a "minimum" in noise floor at B an "opportunity" is identified between A and B.
17
If A has data for B as a final destination or a relay - and the "opportunity" identified by A to B is better than any other "opportunity" to any other station at that moment - A decides to transmit to B.

Fig 2E


18
A choses datarate and packet duration based on the ammount of transmit power available at A and the required signal to noise ratio for different data rates and packet durations at B - taking into account the rate of change of pathloss from A to B and noise at B.
19
A examines its transmit data que destined for B as a final destination or relay and "fills" the packet with data segments - were packet size is determined by data rate and duration decided on for the opportunity.
20
A receives acknowledgement from B or monitors to hear B transmit data further,

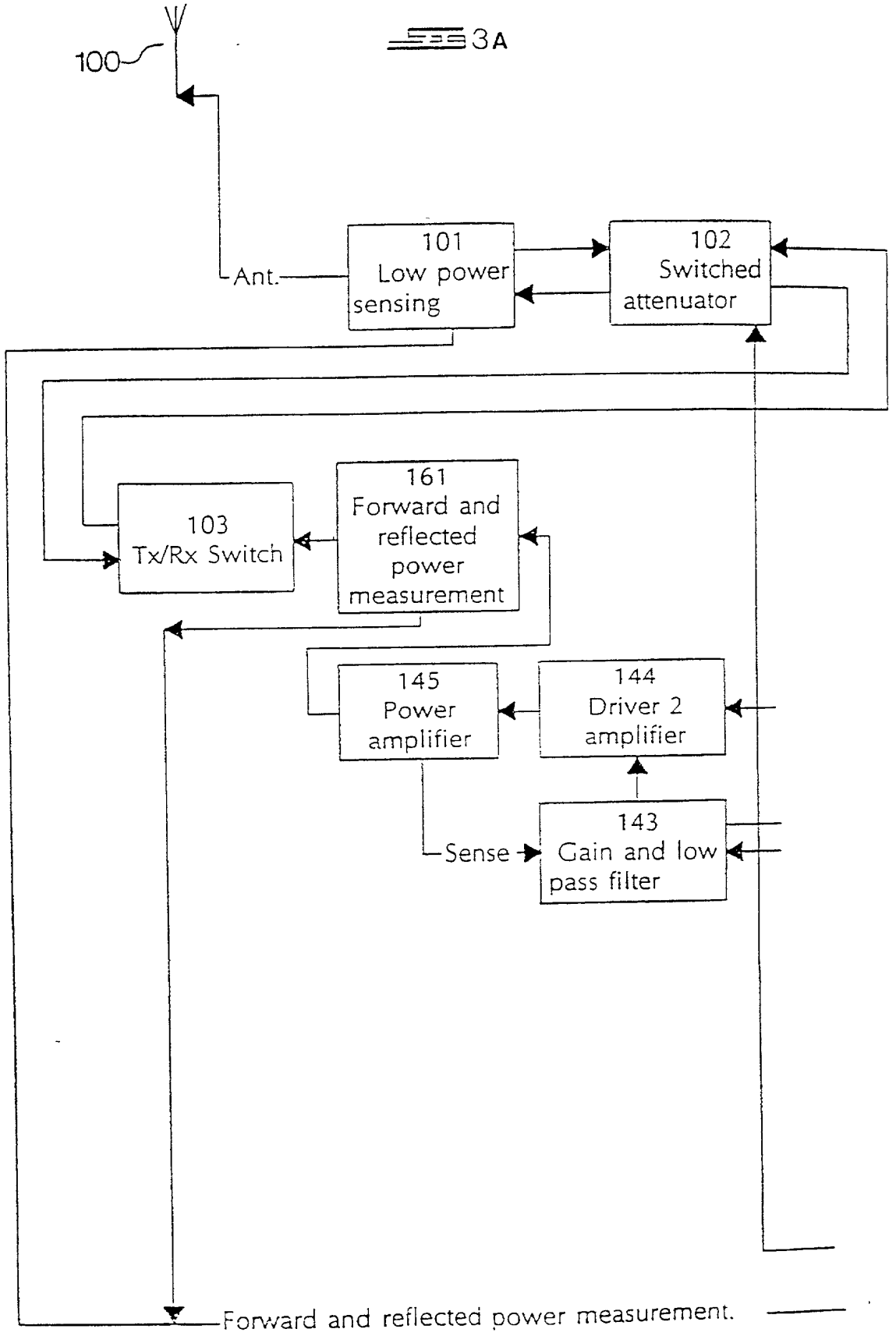


FIG 3A

replaced by this sheet

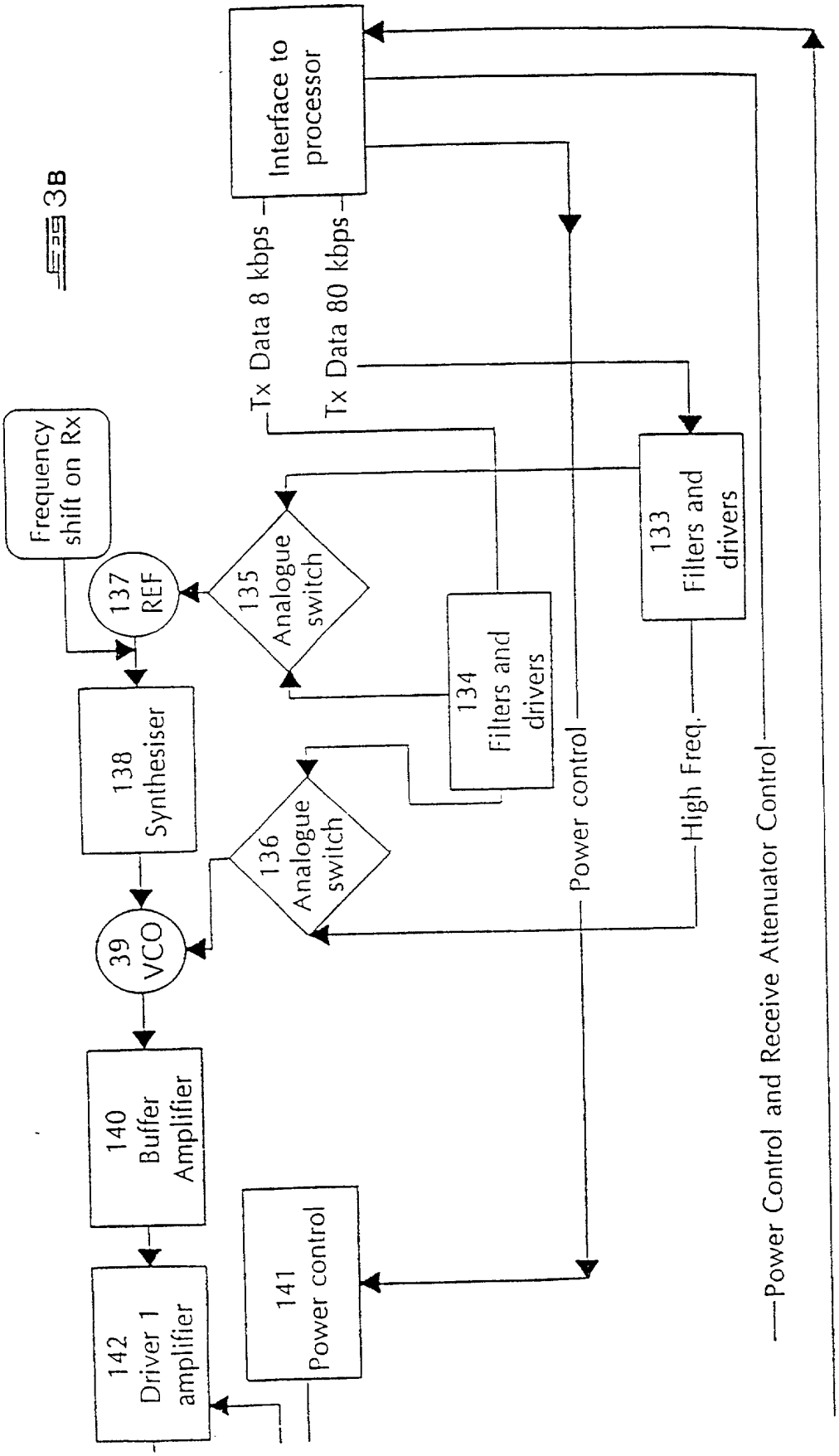

Interface to processor
Tx Data 8 kbps
Tx Data 80 kbps
Frequency shift on Rx
137 REF
135 Analogue switch
133 Filters and drivers
134 Filters and drivers
138 Synthesiser
136 Analogue switch
Power control
High Freq.
39 VCO
140 Buffer Amplifier
141 Power control
142 Driver 1 amplifier
Power Control and Receive Attenuator Control

FIG 3B

Fig 4A

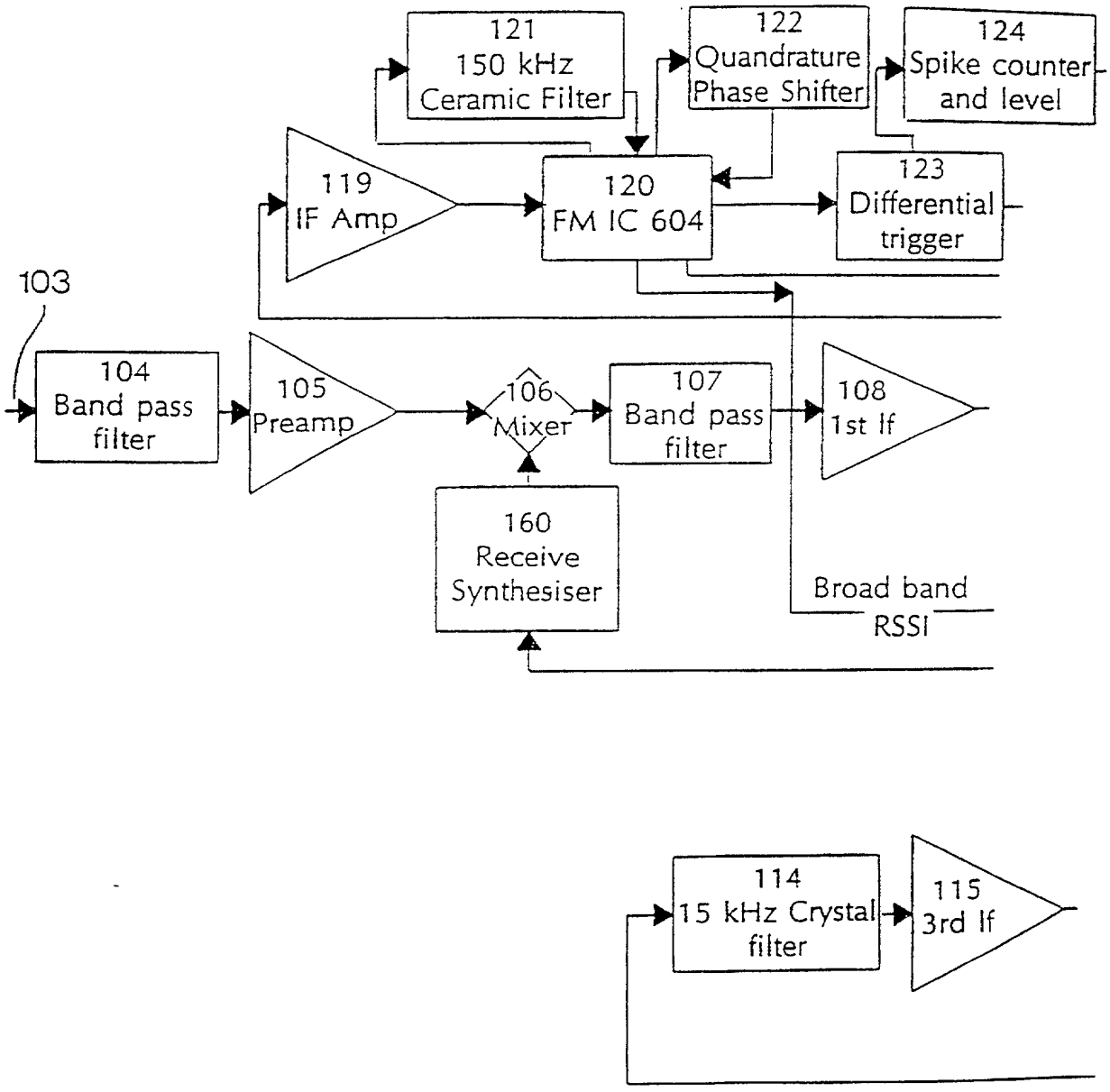

121
150 kHz
Ceramic Filter
122
Quandrature
Phase Shifter
124
Spike counter
and level
119
IF Amp
120
FM IC 604
123
Differential
trigger
103
104
Band pass
filter
105
Preamp
106
Mixer
107
Band pass
filter
108
1st If
160
Receive
Synthesiser
Broad band
RSSI
114
15 kHz Crystal
filter
115
3rd If

Fig 4B

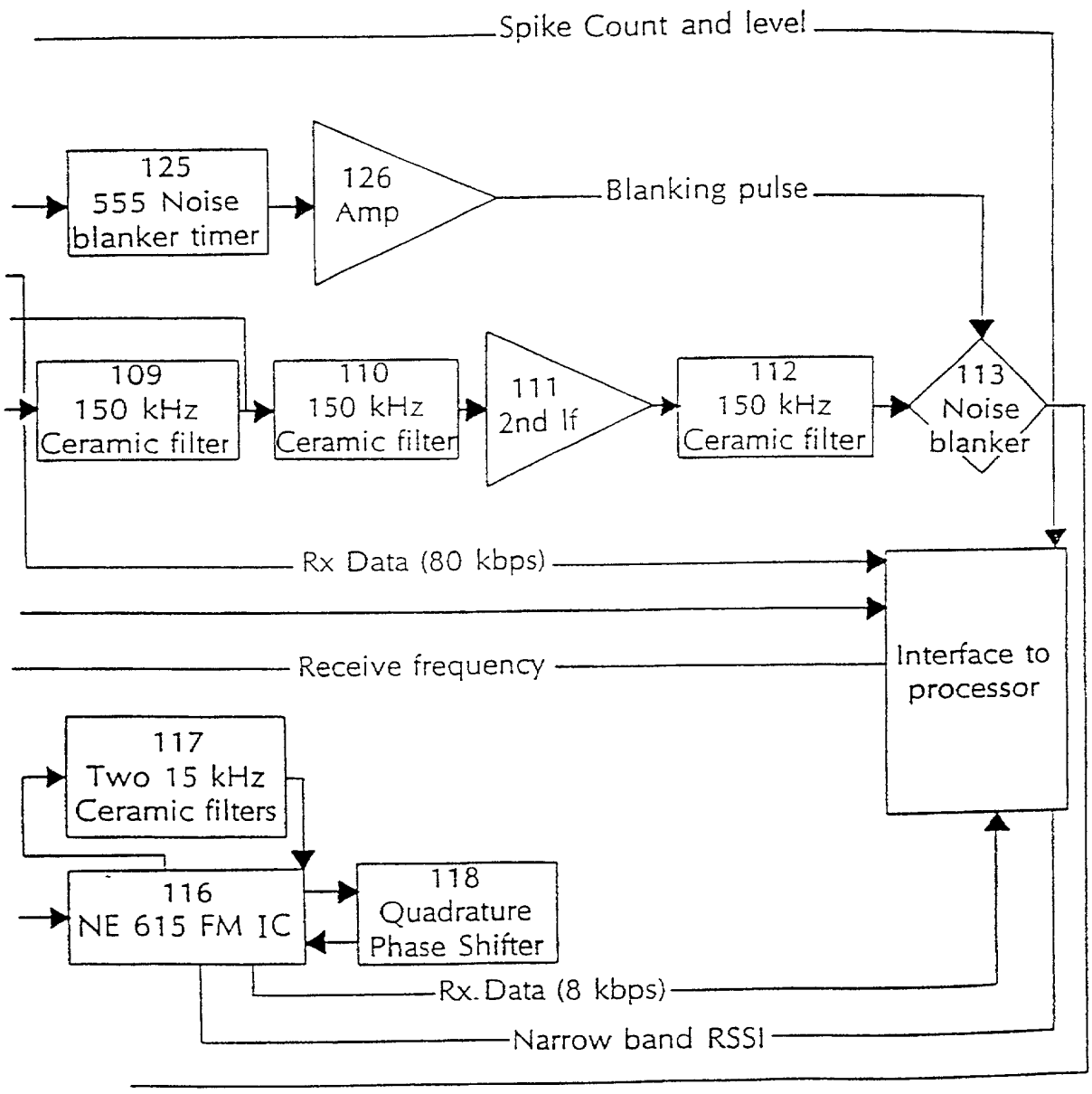


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Fig 5A

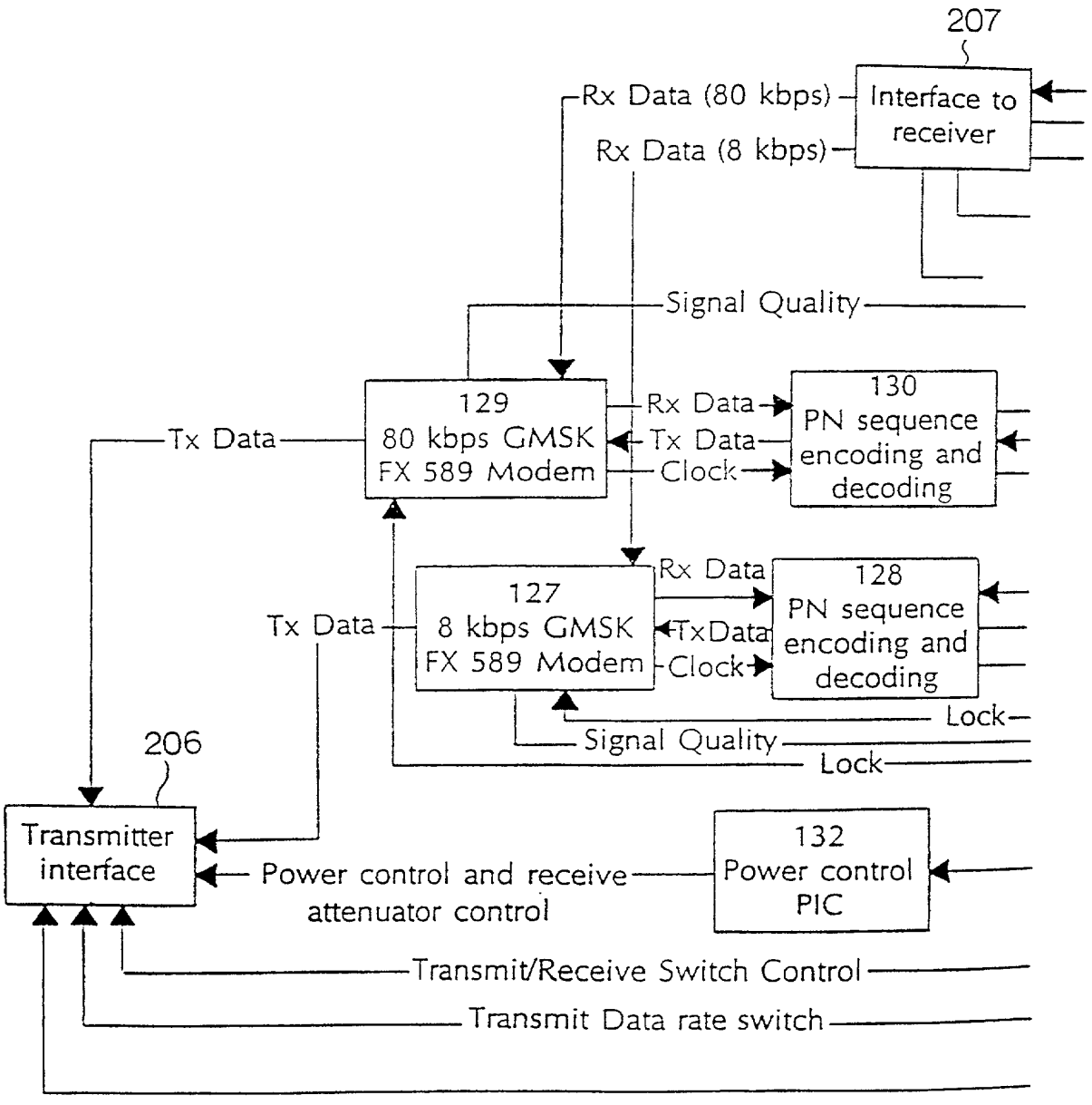
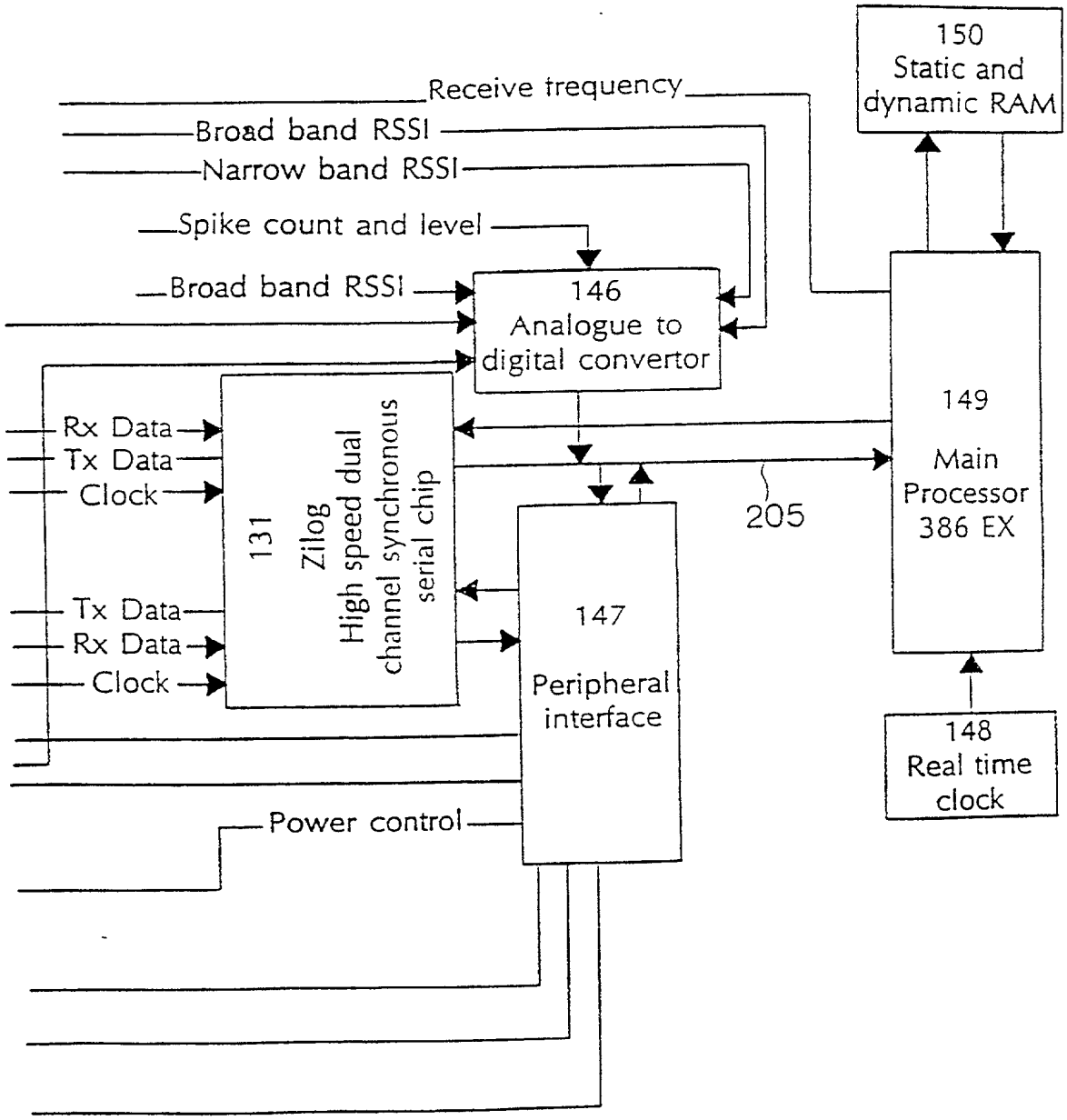

207
Interface to receiver
Rx Data (80 kbps)
Rx Data (8 kbps)
Signal Quality
129
80 kbps GMSK FX 589 Modem
Rx Data
Tx Data
Clock
130
PN sequence encoding and decoding
Tx Data
127
8 kbps GMSK FX 589 Modem
Rx Data
TxData
Clock
128
PN sequence encoding and decoding
Lock
Signal Quality
Lock
206
Transmitter interface
Power control and receive attenuator control
132
Power control PIC
Transmit/Receive Switch Control
Transmit Data rate switch

Fig 5B


150
Static and
dynamic RAM
Receive frequency
Broad band RSSI
Narrow band RSSI
Spike count and level
Broad band RSSI
146
Analogue to
digital convertor
149
Main
Processor
386 EX
Rx Data
Tx Data
Clock
131
Zilog
High speed dual
channel synchronous
serial chip
205
147
Peripheral
interface
Tx Data
Rx Data
Clock
148
Real time
clock
Power control

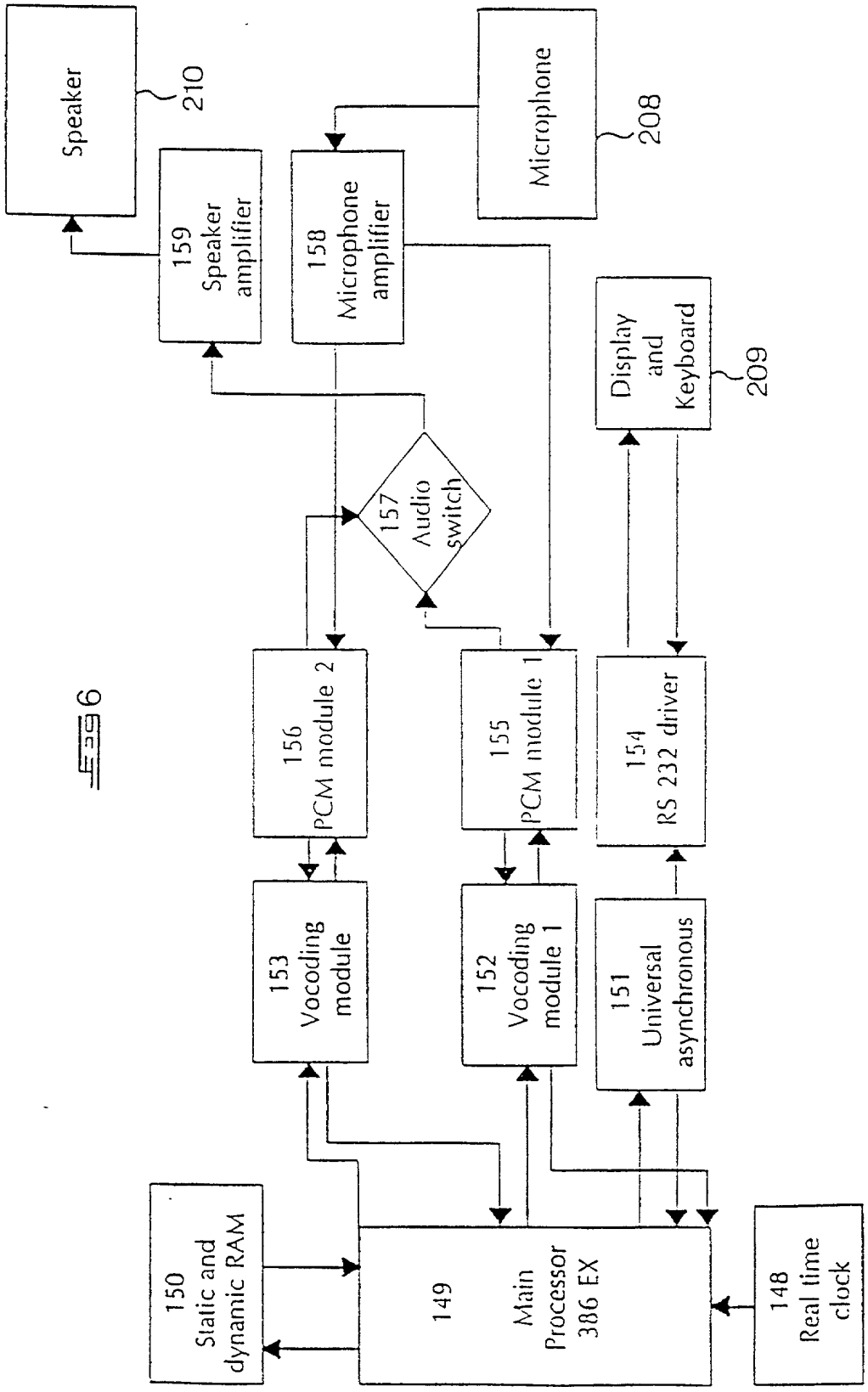


FIG 6

SUBSTITUTE SHEET (RULE 26)

7A

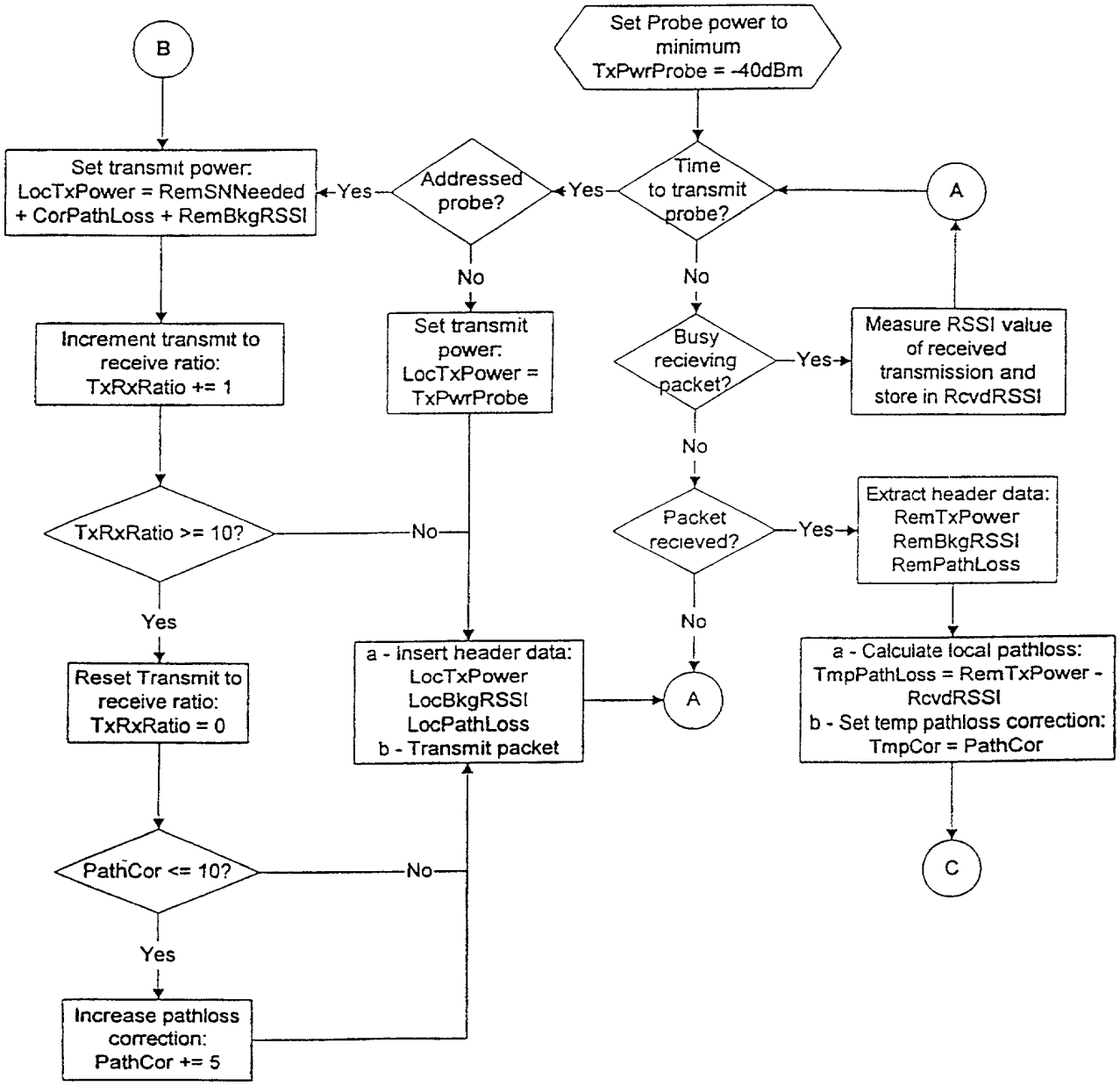

Set Probe power to minimum TxPwrProbe = -40dBm
Time to transmit probe?
Yes
Addressed probe?
Yes
Set transmit power: LocTxPower = RemSNNeeded + CorPathLoss + RemBkgRSSI
No
Busy recieving packet?
Yes
Measure RSSI value of received transmission and store in RcvdRSSI
No
Packet recieved?
Yes
Extract header data: RemTxPower RemBkgRSSI RemPathLoss
No
a - Calculate local pathloss: TmpPathLoss = RemTxPower - RcvdRSSI
b - Set temp pathloss correction: TmpCor = PathCor
C
A
A
B
Increment transmit to receive ratio: TxRxRatio += 1
TxRxRatio >= 10?
No
Yes
Reset Transmit to receive ratio: TxRxRatio = 0
PathCor <= 10?
No
Yes
Increase pathloss correction: PathCor += 5
Set transmit power: LocTxPower = TxPwrProbe
a - Insert header data: LocTxPower LocBkgRSSI LocPathLoss
b - Transmit packet

FIG 7B

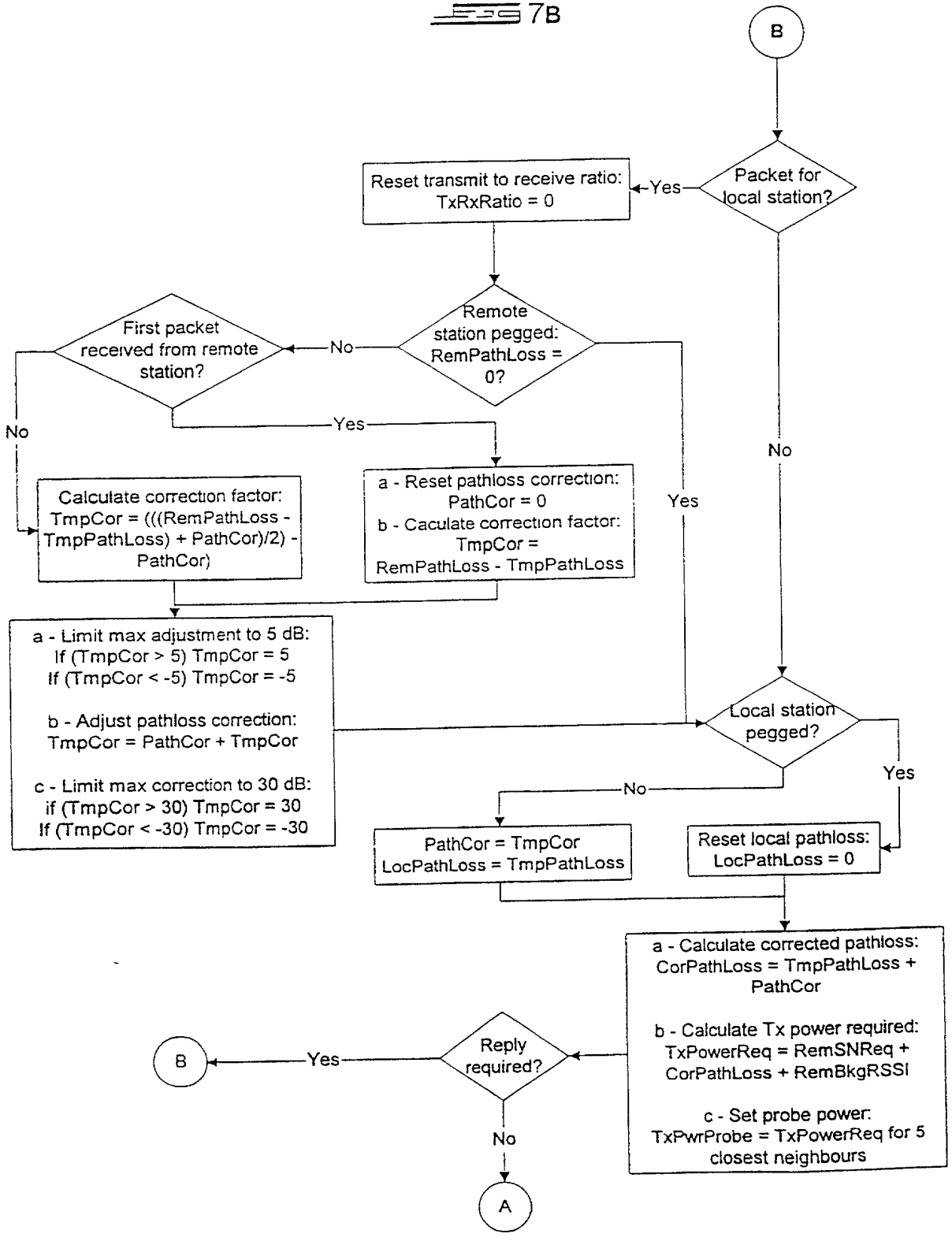

B
Packet for local station?
Yes
Reset transmit to receive ratio: TxRxRatio = 0
No
Remote station pegged: RemPathLoss = 0?
No
First packet received from remote station?
No
Yes
Yes
Calculate correction factor: TmpCor = (((RemPathLoss - TmpPathLoss) + PathCor)/2) - PathCor)
a - Reset pathloss correction: PathCor = 0
b - Caculate correction factor: TmpCor = RemPathLoss - TmpPathLoss
a - Limit max adjustment to 5 dB: If (TmpCor > 5) TmpCor = 5 If (TmpCor < -5) TmpCor = -5
b - Adjust pathloss correction: TmpCor = PathCor + TmpCor
c - Limit max correction to 30 dB: if (TmpCor > 30) TmpCor = 30 If (TmpCor < -30) TmpCor = -30
Local station pegged?
Yes
No
PathCor = TmpCor LocPathLoss = TmpPathLoss
Reset local pathloss: LocPathLoss = 0
a - Calculate corrected pathloss: CorPathLoss = TmpPathLoss + PathCor
b - Calculate Tx power required: TxPowerReq = RemSNReq + CorPathLoss + RemBkgRSSI
c - Set probe power: TxPwrProbe = TxPowerReq for 5 closest neighbours
Reply required?
Yes
B
No
A

FIG 8A

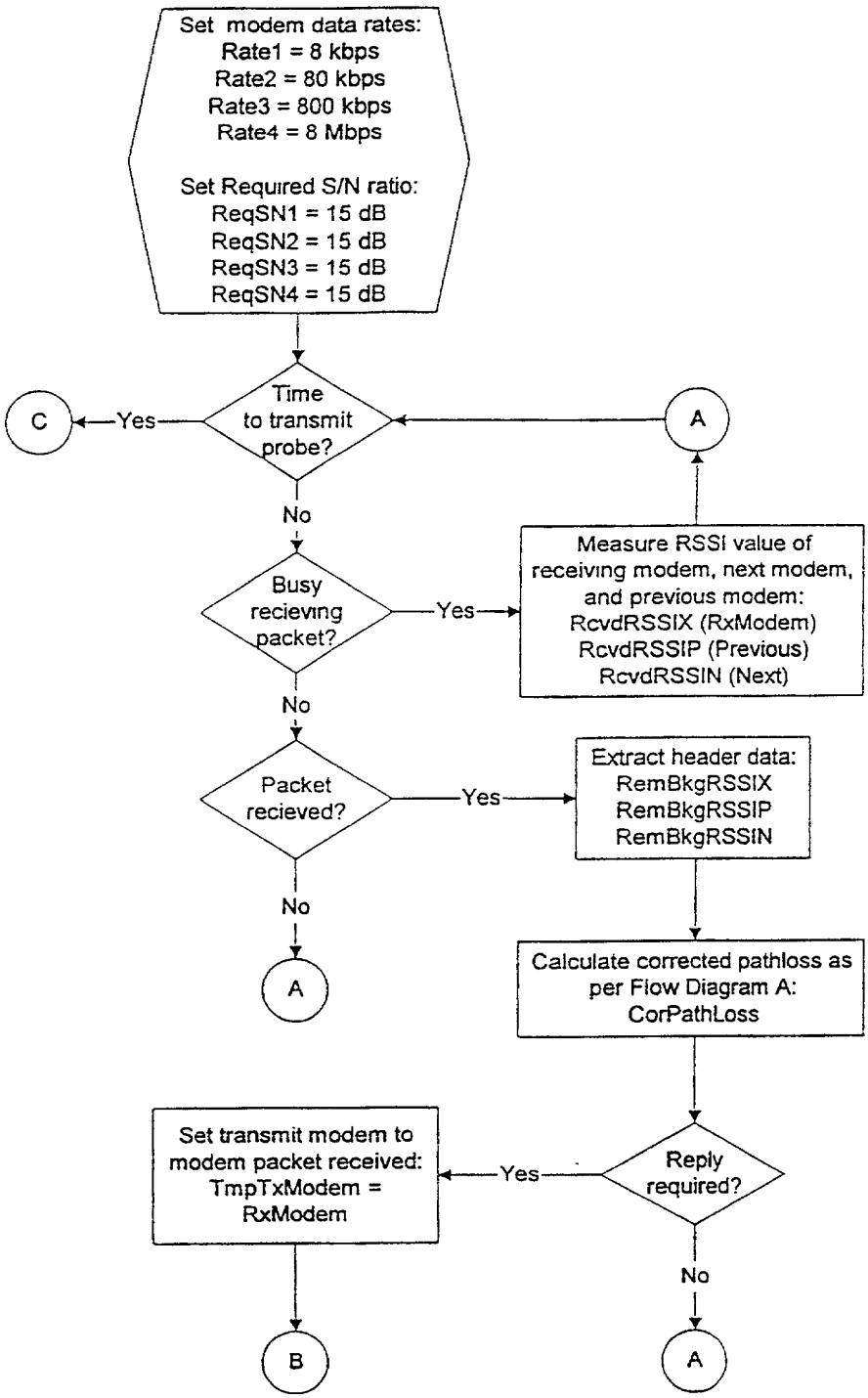

Set modem data rates:
Rate1 = 8 kbps
Rate2 = 80 kbps
Rate3 = 800 kbps
Rate4 = 8 Mbps
Set Required S/N ratio:
ReqSN1 = 15 dB
ReqSN2 = 15 dB
ReqSN3 = 15 dB
ReqSN4 = 15 dB
Time to transmit probe?
Yes
C
A
No
Busy recieving packet?
Yes
Measure RSSI value of receiving modem, next modem, and previous modem:
RcvdRSSIX (RxModem)
RcvdRSSIP (Previous)
RcvdRSSIN (Next)
No
Packet recieved?
Yes
Extract header data:
RemBkgRSSIX
RemBkgRSSIP
RemBkgRSSIN
No
A
Calculate corrected pathloss as per Flow Diagram A:
CorPathLoss
Reply required?
Yes
Set transmit modem to modem packet received:
TmpTxModem = RxModem
No
B
A

FIG 8B

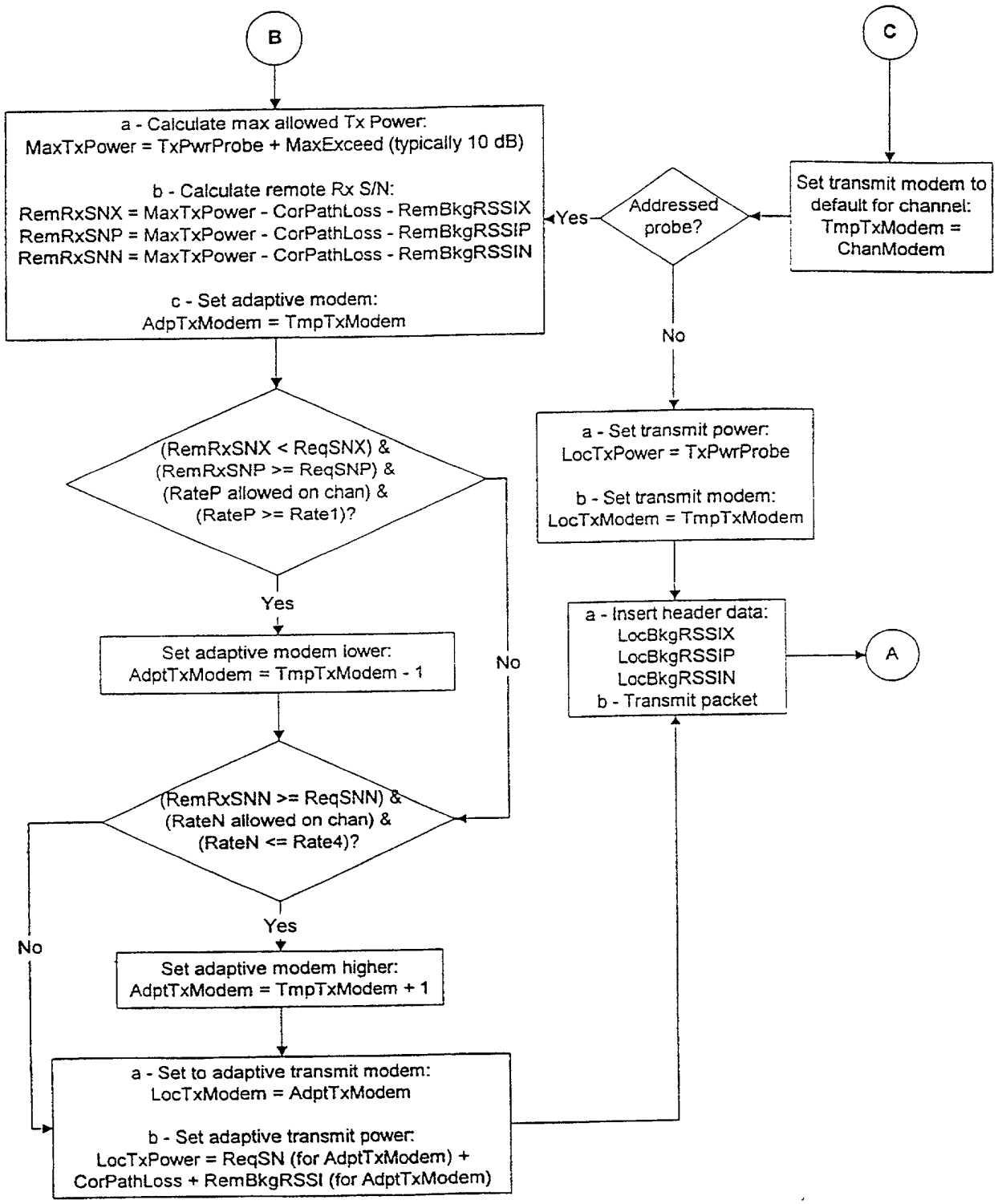

B
C
a - Calculate max allowed Tx Power:
MaxTxPower = TxPwrProbe + MaxExceed (typically 10 dB)
b - Calculate remote Rx S/N:
RemRxSNX = MaxTxPower - CorPathLoss - RemBkgRSSIX
RemRxSNP = MaxTxPower - CorPathLoss - RemBkgRSSIP
RemRxSNN = MaxTxPower - CorPathLoss - RemBkgRSSIN
c - Set adaptive modem:
AdpTxModem = TmpTxModem
Addressed probe?
Yes
No
Set transmit modem to default for channel:
TmpTxModem = ChanModem
(RemRxSNX < ReqSNX) & (RemRxSNP >= ReqSNP) & (RateP allowed on chan) & (RateP >= Rate1)?
Yes
No
Set adaptive modem lower:
AdptTxModem = TmpTxModem - 1
(RemRxSNN >= ReqSNN) & (RateN allowed on chan) & (RateN <= Rate4)?
Yes
No
Set adaptive modem higher:
AdptTxModem = TmpTxModem + 1
a - Set to adaptive transmit modem:
LocTxModem = AdptTxModem
b - Set adaptive transmit power:
LocTxPower = ReqSN (for AdptTxModem) + CorPathLoss + RemBkgRSSI (for AdptTxModem)
a - Set transmit power:
LocTxPower = TxPwrProbe
b - Set transmit modem:
LocTxModem = TmpTxModem
a - Insert header data:
LocBkgRSSIX
LocBkgRSSIP
LocBkgRSSIN
b - Transmit packet
A

FIG 9A

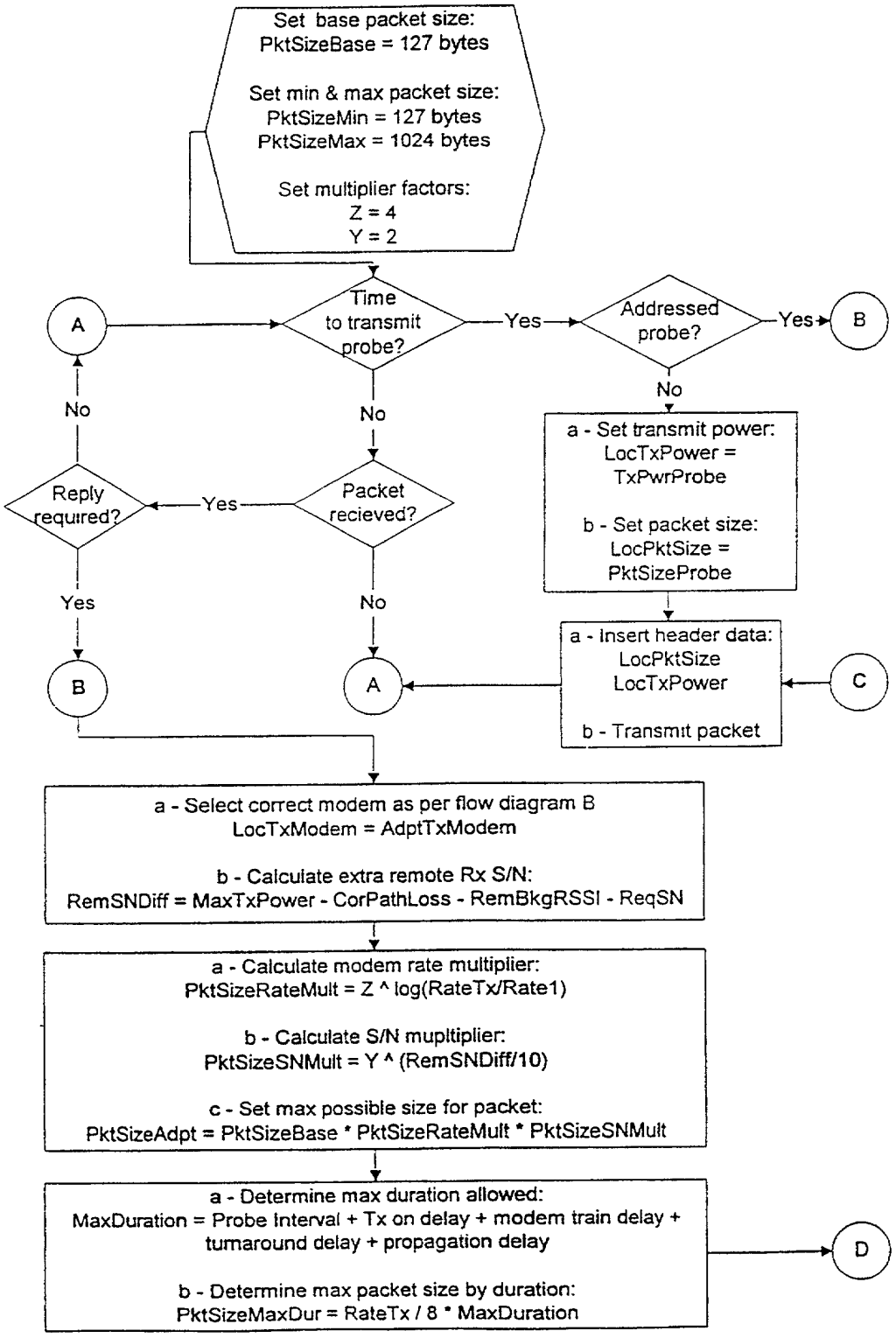
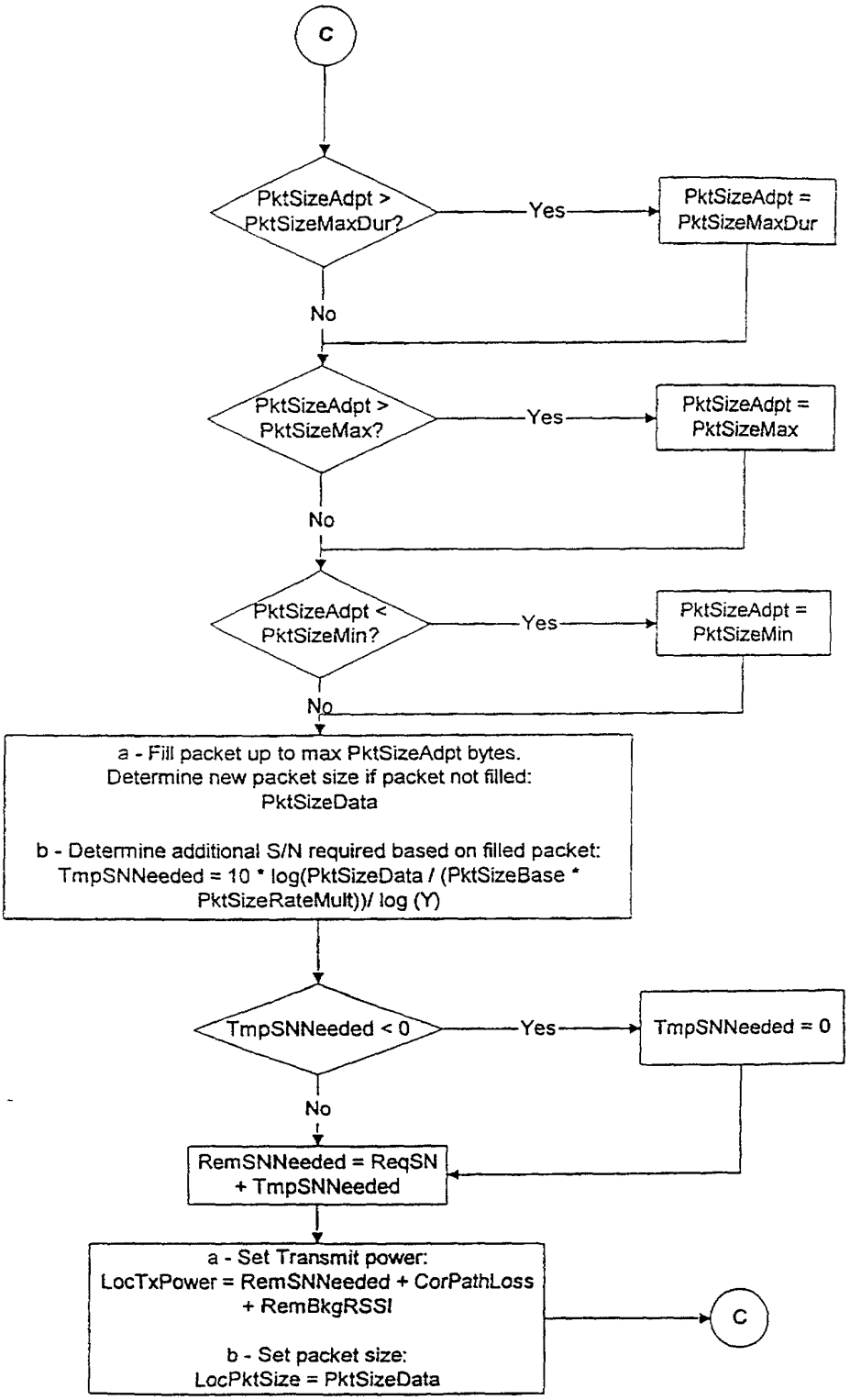

Set base packet size:
PktSizeBase = 127 bytes
Set min & max packet size:
PktSizeMin = 127 bytes
PktSizeMax = 1024 bytes
Set multiplier factors:
Z = 4
Y = 2
A
Time to transmit probe?
Yes
Addressed probe?
Yes
B
No
No
a - Set transmit power:
LocTxPower =
TxPwrProbe
b - Set packet size:
LocPktSize =
PktSizeProbe
No
Reply required?
Yes
Packet recieved?
Yes
No
a - Insert header data:
LocPktSize
LocTxPower
b - Transmit packet
C
B
A
a - Select correct modem as per flow diagram B
LocTxModem = AdptTxModem
b - Calculate extra remote Rx S/N:
RemSNDiff = MaxTxPower - CorPathLoss - RemBkgRSSI - ReqSN
a - Calculate modem rate multiplier:
PktSizeRateMult = Z ^ log(RateTx/Rate1)
b - Calculate S/N mupltiplier:
PktSizeSNMult = Y ^ (RemSNDiff/10)
c - Set max possible size for packet:
PktSizeAdpt = PktSizeBase * PktSizeRateMult * PktSizeSNMult
a - Determine max duration allowed:
MaxDuration = Probe Interval + Tx on delay + modem train delay +
turnaround delay + propagation delay
b - Determine max packet size by duration:
PktSizeMaxDur = RateTx / 8 * MaxDuration
D

FIG 9B


C
PktSizeAdpt > PktSizeMaxDur?
Yes
PktSizeAdpt = PktSizeMaxDur
No
PktSizeAdpt > PktSizeMax?
Yes
PktSizeAdpt = PktSizeMax
No
PktSizeAdpt < PktSizeMin?
Yes
PktSizeAdpt = PktSizeMin
No
a - Fill packet up to max PktSizeAdpt bytes.
Determine new packet size if packet not filled:
PktSizeData
b - Determine additional S/N required based on filled packet:
TmpSNNeeded = 10 * log(PktSizeData / (PktSizeBase * PktSizeRateMult))/ log (Y)
TmpSNNeeded < 0
Yes
TmpSNNeeded = 0
No
RemSNNeeded = ReqSN + TmpSNNeeded
a - Set Transmit power:
LocTxPower = RemSNNeeded + CorPathLoss + RemBkgRSSI
b - Set packet size:
LocPktSize = PktSizeData
C

PATENT

Attorney's Docket No. _____

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL, CONTINUATION OR CIP)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type: *(check one applicable item below)*

- ☐ original
- ☐ design
- ☐ supplemental

NOTE: If the declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application, do not check next item; check appropriate one of last three items.

- ☒ national stage of PCT

NOTE: If one of the following 3 items applies, then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR CIP.

- ☐ divisional
- ☐ continuation
- ☐ continuation-in-part (CIP)

INVENTORSHIP IDENTIFICATION

WARNING: If the inventors are each not the inventors of all the claims, an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.

My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

POWER ADAPTION IN A MULTI-STATION NETWORK

SPECIFICATION IDENTIFICATION

the specification of which: *(complete (a), (b) or (c))*

(a) ☐ is attached hereto.

(b) ☐ was filed on _____ as ☐ Serial No. 0 /_____ or ☐ Express Mail No., *as Serial No. not yet known* _____ and was amended on _____ *(if applicable)*.

NOTE: Amendments filed after the original papers are deposited with the PTO which contain new matter are not accorded a filing date by being referred to in the declaration. Accordingly, the amendments involved are those filed with the application papers or, in the case of a supplemental declaration, are those amendments claiming matter not encompassed in the original statement of invention or claims. See 37 CFR 1.67.

(c) ☒ was described and claimed in PCT International Application No. PCT/GB98/02329 filed on 3 August 1998 and as amended under PCT Article 19 on _____ *(if any)*.

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information

☒ which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56

(also check the following items, if desired)

☐ and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable examiner would consider it important in deciding whether to allow the application to issue as a patent, and

☐ In compliance with this duty there is attached an information disclosure statement in accordance with 37 CFR 1.98.

PRIORITY CLAIM (35 U.S.C. § 119)

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

(complete (d) or (e))

(d) ☐ no such applications have been filed.

(e) ☒ such applications have been filed as follows.

NOTE: Where item (c) is entered above and the International Application which designated the U.S. itself claimed priority check item (e), enter the details below and make the priority claim.

A. PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 USC 119
SOUTH AFRICA	97/6885	1 AUGUST 1997	☒ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐

ALL FOREIGN APPLICATION(S), IF ANY FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

NOTE: *If the application filed more than 12 months from the filing date of this application is a PCT filing forming the basis for this application entenng the United States as (1) the national stage, or (2) a continuation, divisional, or continuation-in-part, then also complete ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR CIP APPLICATION for benefit of the prior U.S. or PCT application(s) under 35 U.S.C. § 120.*

POWER OF ATTORNEY

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*List name and registration number*)

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☐ Attached as part of this declaration and power of attorney is the authorization of the above-named attorney(s) to accept and follow instructions from my representative(s).

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DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

NOTE: Carefully indicate the family (or last) name as it should appear on the filing receipt and all other documents.

1-00

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